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SOME OBSERVATIONS ON THE GROWTH OF ORGANISMS IN WATER PIPES.

BY GEORGE C. WHIPPLE, BIOLOGIST, AND DIRECTOR OF MOUNT PROSPECT LABORATORY, BROOKLYN WATER DEPARTMENT.

[*Read Sept.* 8, 1897.]

The reactions between the water and the water pipes of any water works system are topics of vital importance. They involve such matters as iron rusting, tuberculations, lead poisoning, and others, all of which have been the subject of much study, and some of which are even now but imperfectly understood. Up to the present time, it has been the chemical and physical reactions that have received attention. There is, however, a sort of biological reaction between the water and its conductors which is not unworthy of our consideration.

The question may be approached from two sides. In fact, there are two questions, namely: What effect have the aqueducts and pipes upon the biology of the water, and what effect has the water upon the biology of the aqueducts and pipes? There is comparatively little accurate data to be obtained upon these questions, and as the extensive biological observations of the Boston Water Works, now covering a period of eight years, offer the greatest amount of available material,* they will be used as the basis of the discussion.

*Annual Reports of the Boston Water Works, 1891 to 1895.

It is unnecessary to describe this water supply to the members of this Association, but for the sake of those not familiar with it, it may be well to state that there are two different sources, Lake Cochituate and the Sudbury River. Both are surface waters. The former is a chain of lakes, four miles in length and of considerable depth, that furnishes water light in color, at times rich in microscopical organisms, and containing moderate numbers of bacteria. This is conveyed through a brick-lined aqueduct to the distributing reservoirs at Chestnut Hill and Brookline. The Sudbury River, utilized by the construction of several storage reservoirs, or basins, furnishes a water of rather high color, and one that contains an abundance of organic matter. This water also is conveyed to the Chestnut Hill and Brookline reservoirs, where it mixes with the Cochituate water. From these reservoirs the mixed waters are carried to the city through several lines of 48-inch and 36-inch pipes.

It was the custom, for a number of years, to collect weekly samples of water for analysis at the effluent gate houses of these two reservoirs, at a tap in Park Square, Boston, and at a tap in Mattapan. Occasional samples were taken at other places in the city. The object was to determine the difference in the character of the water in the different sections of the city, and to ascertain what changes took place in the water during its passage through the pipes. The tap in Park Square is about five miles from the Chestnut Hill reservoir, and the tap in Mattapan about eleven miles. Examination of the pipe lines, and a study of the color of the water, show that in all probability the Park Square tap is supplied with water direct from the Chestnut Hill reservoir, while at Mattapan the water comes largely from the Brookline reservoir. This is largely a matter of assumption, however, and as the Superintendent has always taken great pains to keep the mixture of Sudbury and Cochituate water the same in both reservoirs, it matters little for the purposes of this paper whether the water comes from the one or the other. Hence we may say that the chief difference between the two tap samples lies in the different lengths of pipe through which the water passes. It should be borne in mind, however, that as the water flows from the reservoirs to the outer limits of the distribution system, the sizes of the pipes diminish, so that the Mattapan water passes through a greater length of pipe of small size than the water at Park Square.

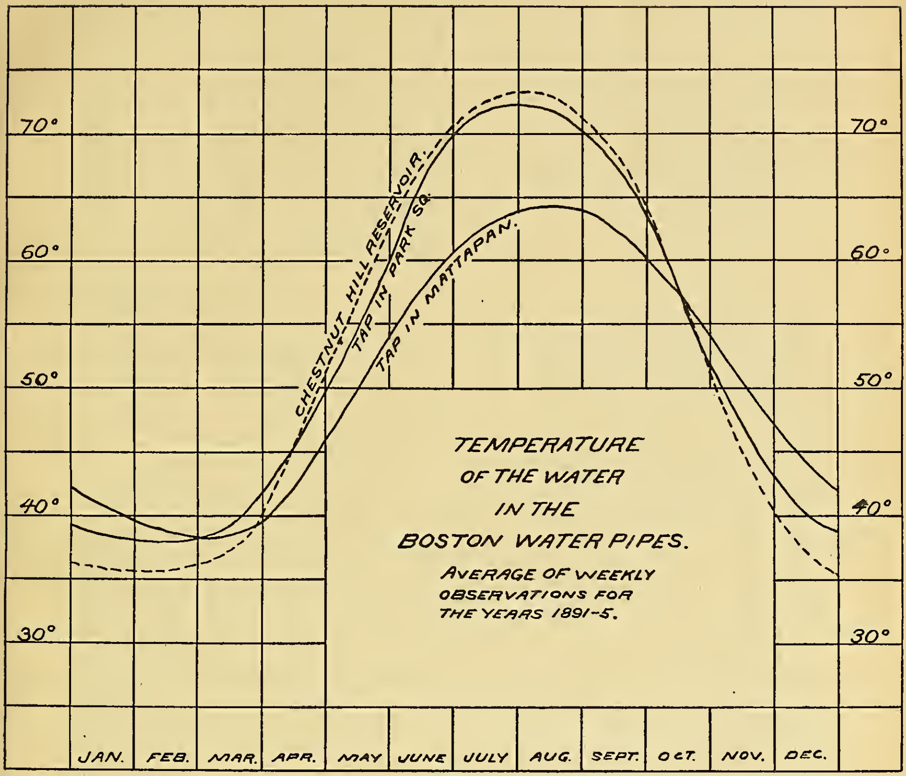

PLATE I.

The temperature of the water at the effluent gate house at Chestnut Hill reservoir, and at the taps mentioned, is shown on Plate I, where the curves represent the averages of weekly observations for five years (1891 to 1895). As would be expected, the greatest range of temperature occurs in the reservoir, though the water in the tap in Park Square agrees with it closely. The effect of the passage of the water through the pipes is well shown by the curves. During the spring and summer the water grows cooler, and during the fall and winter it grows warmer as it passes through the ground. In the summer the water is always several degrees cooler at Mattapan than at Park Square, the greatest difference being observed during July and August. In the winter the minimum temperature at the two taps is about the same, but at Park Square the lowest

point is reached in February, while at Mattapan it is found one month later. A comparison of the mean monthly temperatures for each year is given in Table I.

If we consider the results of the biological examinations, as published in the annual reports of the Boston Water Works, we shall find that for the five years from 1891 to 1895, the microscopical organisms and amorphous matter were present, as follows:

	Number of Standard Units per c. c.	
	Organisms.	Amorphous Matter.
Chestnut Hill reservoir, gate house	248	209
Brookline reservoir, gate house	215	212
Tap in Park Square	194	190
Tap in Mattapan	84	105

If we assume that the water at the Park Square tap comes from the Chestnut Hill reservoir, and that at the Mattapan tap from Brookline reservoir, we shall find that during its passage from Chestnut Hill reservoir to Park Square the water lost 22 per cent. of its organisms and 9 per cent. of its amorphous matter; while from Brookline reservoir to Mattapan it lost 61 per cent. of its organisms and 50 per cent. of its amorphous matter. If we assume that both taps receive the mixed water from both reservoirs, we find that during its passage through about five miles of pipes the water lost 16 per cent. of its organisms and 10 per cent. of its amorphous matter; and through eight miles of pipe, 64 per cent. of its organisms and 50 per cent. of its amorphous matter. The greater part of the reduction is seen to occur not near the reservoirs where the pipes are large and the currents great, but in the extremities of the distribution system, where the pipes are smaller. It will be sufficient and somewhat simpler to consider only the two taps.

Tables II. and III. show the number of microscopical organisms and the amount of amorphous matter in the water at Park Square and Mattapan for each month during a period of five years. The figures are based on weekly examinations. The averages for the whole period are given in the last two columns. The latter are also shown graphically on Plate II. Study of the plate and tables shows that during the winter, when there are comparatively few organisms in the water, the reduction in the pipes is much less than during the summer, when organisms are more abundant. We find by

calculation that during the six months of the year, from November to April, there is a reduction of 44 per cent. in organisms and 24 per cent. in amorphous matter in passing through about six miles of pipe; while during the six months from May to October the reduction is 62 per cent. for the organisms and 53 per cent. for the amorphous matter. It is interesting to note that the reduction in organisms is greater than the reduction in amorphous matter.

Not only are the microscopical organisms and amorphous matter reduced in the pipes, but the bacteria also tend to decrease. This fact has been observed several times in other cities. The figures presented in Table IV. show that in the pipes of the Boston Water Works the decrease does not occur throughout the entire year. In the summer, when the temperature of the water is high and when the organisms in the water and those growing in the pipes are passing rapidly through stages of growth and decay, there is a considerable increase. This is seen best by the aid of the diagram (Plate II.). That it is no accidental observation is shown by the fact that it occurs regularly each year, and that the same results were obtained whether the samples were plated at the time of collection or after transportation to the laboratory.

In order to determine what organisms showed the greatest reduction in the pipes, a more detailed study of the examinations was made for the years 1892 and 1893. The following were the results:

Percentage Reduction of Microscopical Organisms in the Distribution Pipes Between Park Square and Mattapan.

	Average for the years 1892 and 1893.
Diatomaceæ	58 per cent.
Chlorophyceæ	57 " "
Cyanophyceæ	54 " "
Infusoria	64 " "
Miscellaneous	58 " "
Organisms of all kinds	56 " "

It appears that the infusoria are reduced the most and the cyanophyceæ the least. The difference between the two is slight, however.

Examinations of the Mystic water supply at College Hill reservoir and at a tap in Chelsea also show a reduction in organisms and amorphous matter during the passage of the water through the

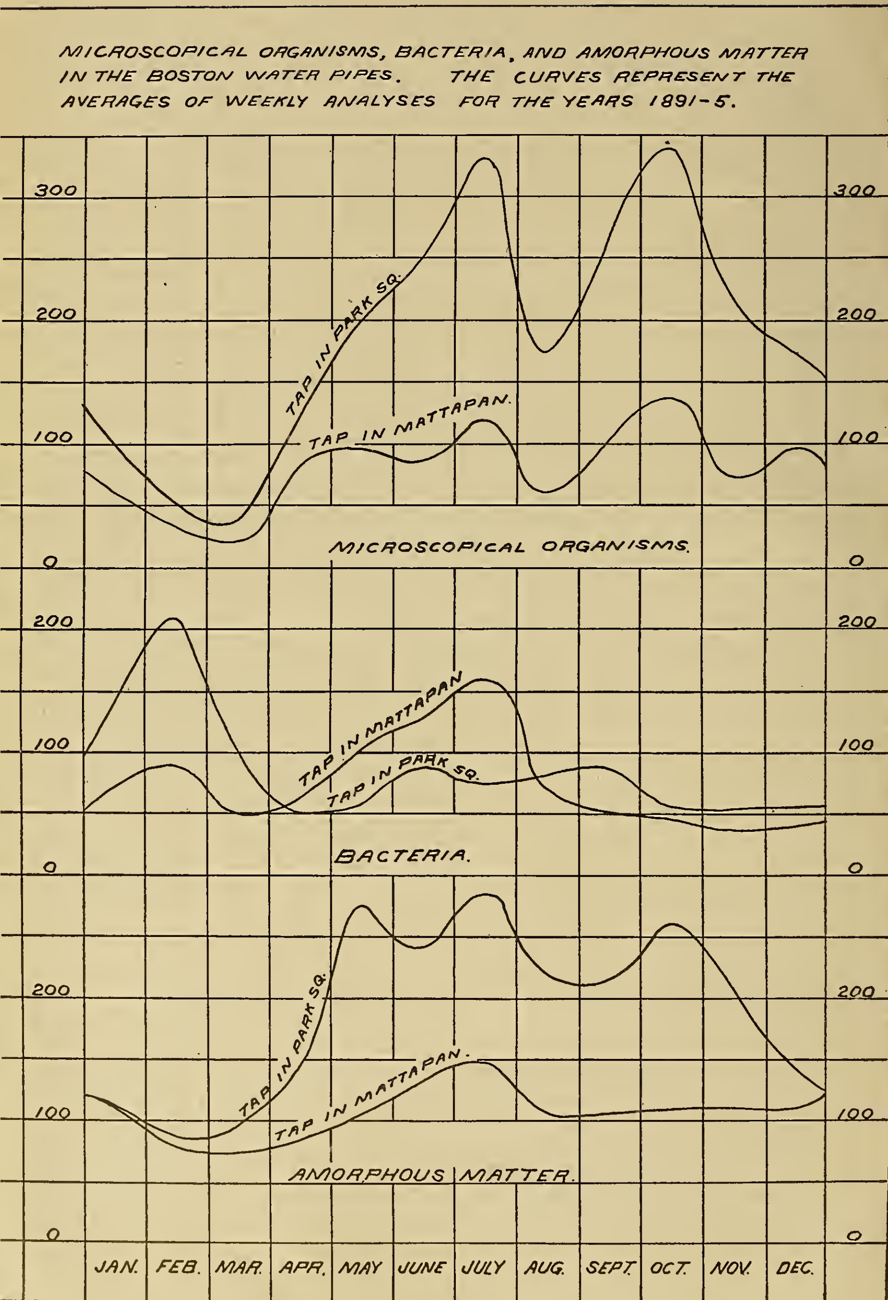
MICROSCOPICAL ORGANISMS, BACTERIA, AND AMORPHOUS MATTER IN THE BOSTON WATER PIPES. THE CURVES REPRESENT THE AVERAGES OF WEEKLY ANALYSES FOR THE YEARS 1891-5.
300
200
100
0
TAP IN PARK SQ.
TAP IN MATTAPAN.
MICROSCOPICAL ORGANISMS.
TAP IN MATTAPAN
TAP IN PARK SQ.
BACTERIA.
TAP IN PARK SQ.
TAP IN MATTAPAN.
AMORPHOUS MATTER.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

PLATE II.

pipes. Table V, which represents the results of monthly examinations for four years, shows that the average reduction of organisms was 41 per cent. and of amorphous matter, 52 per cent. The bacteria were usually lower at the tap, but occasionally an increase in the pipes was noticed.

Questions naturally arise as to the cause and effect of this reduction of organisms in the pipes. We may consider them under the following topics: sedimentation, disintegration, decomposition, and consumption by other organisms.

Most, and probably all, of the microscopical organisms are heavier than water. Some always settle in quiet water, and they do so in the pipes whenever the current is reduced to a certain point. Others, which in ponds usually rise to the surface on account of the gas bubbles which they contain, will settle in the pipes when the pressure of the water has deprived them of their gas. In dead ends the organisms and particles of amorphous matter often accumulate and form deposits upon the bottom of the pipes. They also tend to deposit on up-grades. It is a matter of frequent observation that the water from the high points of a distribution system contains fewer organisms than that from the low points. The same fact has been observed in high buildings, where the difference between the water on the upper stories and that on the lower floor is often considerable.

Many of the common organisms are very fragile. Even a slight agitation of the water will break them up. This is particularly true of certain infusoria. It is easy to understand, then, how the subjection to the pressure and the currents of a distribution system causes them to go to pieces. No better example can be found than the Uroglena. A cluster of delicate organisms, embedded in a gelatinous material, upon the outer surface of a sphere, it is one of the most fragile organisms imaginable. A slight pressure or agitation will rupture the colony, and scatter and disintegrate the individuals. In the epidemics of Uroglena that have afflicted so many of our New England ponds, it has been found almost invariably that the Uroglena were abundant in the water of the reservoir, but not in the tap water. By their disintegration the oil globules, which are the cause of the vile fishy odor, are liberated, with the result that the water at the tap almost always smells and tastes worse than the water at the source. This disintegration, with

liberation of oil globules, occurs to some extent in organisms that could hardly be called fragile. The diatoms, which have siliceous cell walls, sometimes go to pieces in the pipes, causing an increase in the odor of the water. This was observed in the recent epidemic of Asterionella in Brooklyn, N. Y.

The organisms found in surface waters are accustomed to live in the light. When they enter the dark pipes they are liable to die and decompose. This is particularly true of some of the organisms that are abundant in the summer. Microscopical examination of samples from the service taps have often revealed organisms in a decomposing condition, swarming with bacteria. This decomposition tends to reduce the numbers of organisms in the pipes.

Another important consideration in the reduction of organisms is the fact that in many of the distribution systems where surface waters are used the pipes are covered with growths of sponge, etc. These attached growths depend for their food material upon the minute organisms found in the water. If the growths are abundant, the removal of organisms from the water from this cause may be considerable. This naturally brings us to our second topic,—the growth of organisms in the pipes.

Comparatively little has been written about the subject in this country. Our attention has been called to growths of Crenothrix and of Fresh Water Sponge, but no attempt has been made to give an accurate account of the organisms infesting the distribution systems of our water supplies. In Europe, however, we find that the subject has been considered to some extent.

In the city of Hamburg the "Minute animals inhabiting water pipes were studied by Hartwig Petersen* in 1876. Ten years later Karl Kraepelin† made a more extended study. His observations are of much interest. He found an animal growth, often more than one centimetre thick, covering the entire surface of the pipes. The composition of this growth varied in different places. He gives a list of sixty different species observed. In many places the walls of the pipes were covered with fresh water sponges, chiefly Spongilla fluviatilis and S. lacustris. Mollusks were conspicuous, especially

*Hartwig Petersen, "Die Bewohner der Hamburger Wasser-leitung," in Vehandl. d. Vereins f. Natur. Unterhaltung. II. Bd., Hamburg, 1876.

†Karl Kraepelin, "Die Fauna der Hamburger Wasser-leitung," Abhandl. d. Naturw. Vereins in Hamburg. IX. Bd., Heft. I., 1886.

the mussel Dreyssena polymorpha. Snails were also numerous. Hundreds of "water lice" (Asellus aquaticus) and "water crabs" (Gammarus pulex) were found at every examination. The material known as "Pipe moss" was common, and consisted largely of Cordylophora lacustris and the Bryozoa Plumatella and Paludicella.

At the time when Crenothrix was giving so much trouble at Rotterdam, Hugo de Vries* made an extended study of the animals and plants found in the water pipes of that city. His observations were confined chiefly to the pipes and canals which conveyed the unfiltered water of the River Maas to the filter beds. In speaking of one of the canals he says, "The walls were thickly covered with living organisms up to the water level. They formed an almost continuous coating of changing composition. There were only one or two exceptions to this. In one place, where the water came from the pumps with great velocity, the walls were free from living organisms; and in another place, where there was almost no current, only one living form was seen. There was one section of one of the canals, where a gentle current was flowing, that was a magnificent aquarium. The walls were everywhere covered with white tufts of fresh water sponge (Spongilla fluviatilis.) Many of these tufts reached a diameter of six or eight inches, but most were somewhat smaller than that. Between the sponge patches were seated countless numbers of the mussel Dreyssena polymorpha. Individuals old and young were often seen grouped together in colonies which sometimes extended completely over the sponges. But what most of all attracted attention was a luxurious growth of the "Horn-polyp," Cordylophora lacustris. It covered the mussel shells and occupied all the space between the sponges. The stalks reached a length of an inch or more. On and between the Cordylophora swarmed countless numbers of Vorticella, Acineta, and other infusoria and rotifers. These organisms had no lack of food material and the absence of light protected them from many foes which, in the light, thin out their ranks. Over all these animals Crenothrix was found growing in abundance. The shells of the mussels and the stems of the "Horn-polyps" were coated with a thick felt-like layer of these iron bacteria." In other localities in the pipes the place of the

*Hugo de Vries, "Die Pflanzen und Thiere in dem dunkelln Raumen der Rotterdamer Wasser-leitung." Jena, 1890.

"Horn-polyps was occupied by the Bryozoa, or "Moss animalcules." All of these branching forms were spoken of collectively by the workmen as "Pipe moss."

In the summer of 1896, when the pipes of the Metropolitan Water Works were being laid in Beacon street, near the Chestnut Hill reservoir, a 16-inch main leading from the Fisher Hill reservoir to the Brighton district was opened. This afforded an opportunity to examine the material on the inside of a pipe that had been laid ten years. Inspection showed that besides the usual coating of iron rust, tubercles. etc., there were numerous patches of fresh water sponge (both Spongilla and Meyenia), brownish or almost white in color, and about the size of the palm of one's hand. What was most conspicuous, however, was a sort of brown matting which covered much larger areas, and which had a thickness of about ¼ inch. It had a very rough surface and, when dried, reminded one of a piece of coarse burlap. This proved to be an animal form belonging to the Polyzoa, and known as Fredericella. As fragments of it had several times before been observed in the water from the service taps, and as it had been seen growing in some small pipes connected with the filtration experiments at Chestnut Hill reservoir, more extended observations were made in different parts of the distribution system.

These brought out the fact that sponges and Polyzoa are well established in the pipes. Many other kinds of organisms were also observed. In some places almost pure cultures of Stentor and Zoothamnium were found. At other points hosts of different organisms were seen, such as snails, mussels, Hydra, Nais and Anguillula, Acineta, Vorticella, countless numbers of ciliated infusoria; Arcella, Amœba, and many other forms. The growths were distinctly animal in their nature, though in many cases parasitic vegetable forms such as Achlya, Crenothrix, Leptothrix, etc., were common. The most important class of organisms, however, was the Polyzoa, of which Fredericella and Plumatella were the chief representatives.

The Polyzoa, or the Bryozoa as they are usually called on the continent, are animals that in some respects resemble the hydra-like polyps. They form colonies that sometimes extend to enormous proportions, hence the appropriateness of their name "Polyzoa," which means "many animals." In the adult stage they lead a sedentary life, firmly attached to some submerged object. The animals

themselves are small, but easily visible to the naked eye. Some of them are covered with a secreted coating, or sheath, that takes the form of narrow, brown-colored tubes; others are imbedded in a mass of jelly. The genera that live in the brown, horny tubes, are the ones that most interest us. They form tree-like growths that often attain considerable length. The branches of the little trees are sometimes an inch long, and each one is the home of an individual polyzoon, or polypide. The branches, or hollow twigs, are separated from the main stalk by partitions, so that, to a certain extent, each polypide lives a separate existence in its own little case, though each was formed from its next lower neighbor by a process of budding. The horny covering is formed of a chemical substance allied to chitin, though in some genera it is calcareous.

The most conspicuous part of the animal is always the circlet of ciliated tentacles. They are mounted on a sort of platform, or disc, called a lophophore, at the forward end of the body. This lophophore, with its crown of tentacles, may be protruded from the end of its protective tube at the will of the animal. The tentacles themselves may be expanded, giving a beautiful, bell-shaped, flower-like appearance. They are hollow, and are covered with fine hair-like processes, or cilia. They are also muscular, and can be bent and straightened at will. By their combined action, powerful currents in the water are set up towards the mouth of the animal, which is situated just beneath the lophophore. Minute organisms are thus swept in as food. In some genera the food material may be watched in its progress through the alimentary canal, but in the animals that dwell in the horny tubes we can only see it disappear into the tube. The animals when disturbed have the power of instantly retracting their tentacles, and this sudden retraction, together with the sly and cautious way in which they afterwards extend them, have long since made the Polyzoa objects of great interest to students of the microscope.

The number and arrangement of the tentacles vary in different genera. In Paludicella, for example, they are 16 in number, arranged in a circle; in Fredericella there are 24, arranged in a sort of oval; while in Plumatella they are much more numerous, and are arranged in a double row in the shape of a crescent or horseshoe.

The body of the organism is a transparent membranous sack, immersed in the jelly or concealed in the brown opaque sheath. It

contains a U-shaped alimentary canal, with a contractile oesophagus, stomach, and intestine; a muscular system that permits some motion within the case, and that causes the extension and contraction of the tentacles; mesentaries in the form of fibrous bands; an ovary, and a rudimentary nervous system. There is no heart nor blood vessels of any kind.

The Polyzoa increase by a process of budding which gives rise to the branched stalks, as we have before remarked. There is also sexual reproduction. In old colonies, especially late in the season, there are often seen small, rounded brown bodies, which, as the animals die, float to the surface of the water. They are the winter eggs, or statoblasts. They are formed within the body, and escape only when the Polyzoon dies, when they emerge, and remain unchanged until the warmth of spring develops them. These statoblasts vary in shape in the different genera and are a valuable aid in identifying species.

The favorite habitat of the Polyzoa is some pond or gently flowing stream where microscopical organisms are plenty. They are often found on the under side of some old board or log. They were once seen covering the entire wood-work of an old dam. They choose shady spots, as a rule, though occasionally they are found in the full glare of sunlight.

They are often found in our water supplies, in the ponds, reservoirs, aqueducts and pipe lines. Boston is by no means the only city where they are met with. They have been observed in many other cities both in New England and elsewhere. Potts speaks of them as being found in the gate houses of the Philadelphia supply, and we have previously referred to their presence abroad. The branching forms seem to be the most important, but the jelly forms are not uncommon. Potts* found the Pectinatella in Fairmount reservoir, Philadelphia, and Crystatella has been often noticed in some of our New England supplies. Perhaps the most notable case of the latter occurred recently in Cape Pond, the water supply of Rockport, Mass. It developed there in great quantities, and was especially abundant on the wood-work at the mouth of the suction pipe. It caused more or less trouble by fouling the sides of the

*E. Potts, "On the Minute Fauna of Fairmont Reservoir," Proc. Acad. Nat. sci., Philadelphia, 1884, pp. 217-219.

stand-pipe, and threatened to become a serious nuisance. The jelly secreting Polyzoa, so far as I am aware, have never been actually observed in the pipes of any water supply.

The fact that the organisms that dwell in water pipes depend for their food material upon the algæ, infusoria, etc., contained in the water, may be easily demonstrated by experiment. Specimens of Fredericella and Plumatella were once placed in a series of jars, some of which were supplied with water rich in its microscopic contents, while others were supplied with the same water after filtration. All the jars were kept in semi-darkness at the same temperature, and were examined daily. The Fredericella and Plumatella that had been supplied with filtered water soon began to die, while those in the other jars lived as long as the experiment was continued. Some of the same Polyzoa were placed in jars furnished with water from the Newton supply, and after about a week they died for want of food. This agrees with what I have learned from the officials of the Newton and Brookline Water Works, that in the distribution pipes of those places such organisms as sponges and Polyzoa are never found. Both supplies are ground water. Dr. G. H. Parker* once made a similar experiment on fresh water sponge, and obtained the same result.

With these facts established, we may confidently affirm that fresh water sponge, Polyzoa, and similar pipe-dwellers will be absent from water pipes where ground water, or water that has been effectively filtered, is used.

One naturally asks, "What is the effect of these organisms growing in the pipes?" In a certain sense they tend to improve the quality of the water by reducing the number of floating microscopical organisms; but they themselves must in time decay, and anyone whose nose has ever had an experience with decomposing sponge will appreciate the fact that better places for these organisms may be found than the distribution systems of our water supplies. It should be stated, however, that in all probability very large quantities would be required in order to produce tastes or odors that would be noticed in the water. No authentic case of trouble from

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*G. H. Parker, Experiments on Fresh Water Sponge, Special Report of the Mass. St. Bd. of Health, 1890, p. 618.

this cause has been thus far recorded, so far as I am aware. Perhaps the greatest objection to their presence, is the fact that they tend to impede the flow of water in the pipes. When one considers that a coating $\frac{1}{4}$ inch thick diminishes the area of the cross-section of a 24-inch pipe by 4 per cent, and of a 6-inch pipe by 15 per cent, and when one learns that these organisms often form layers even thicker than this, it will be seen that such growths are matters of no little importance. Furthermore, fingers of the fresh water sponge sometimes extend several inches into the water, and the matting of the Polyzoa is always rough on account of the stiff branches that are extended into the water in order that the organisms may secure their food. This roughness of the surface must increase the friction of the pipe by an indefinite, but considerable amount.

Summing up the results of these few observations, we learn:

That during the passage of a surface water through the pipes of a distribution system there is ordinarily a considerable reduction in the number of organisms, due to sedimentation, disintegration, decomposition, and consumption by other organisms.

That there is a similar decrease in the number of bacteria, except during those periods of the year when decomposition is going on in the pipes.

That growths of fresh water sponge, Polyzoa, etc., are liable to occur in the distribution pipes of any surface water supply.

That these growths tend to reduce the capacity of the pipes, by diminishing the area of the cross-section and by increasing the friction.

That by their decay, they tend to the production of bad tastes and odors, though it is probable that very large amounts are necessary to give serious trouble.

That these growths of sponge, "pipe-moss," etc., depend upon the minute organisms in the water for their food supply, and that they will die when deprived of them.

And that because of this fact, these growths do not occur in pipes, where the supply is a ground or a filtered water free from microscopic forms.

TABLE I.

TEMPERATURE OF THE WATER IN THE DISTRIBUTION PIPES, BOSTON, MASS.
(Fahrenheit Degrees.)

MONTH.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	39.9	42.0	38.1	43.4	36.7	38.5	41.3	39.6	37.6	40.3	38.7	40.8
February	40.7	39.9	38.8	40.3	36.1	35.9	37.0	38 1	36.9	38.9	37.9	38.6
March	41.8	39.9	36.8	38.9	35.8	36.0	41.9	38.9	38.0	36.6	38.9	38.1
April	48.8	44.2	46.8	43 6	41.7	39.6	46.4	43.1	43.2	40.1	45.4	42.1
May	56.2	50.7	55.1	49 1	53.7	47.9	59.3	51.1	57.5	49.9	56.4	49.7
June	64.4	56.9	69.0	57 2	65.7	57.2	66.3	57.7	66.7	59.1	66.4	57.6
July	70.8	60.6	73.1	62.9	71 7	62.7	73.6	63.9	69.2	63.2	71.7	62 7
August	72.1	62.9	72.9	64.5	71.1	64.5	72.4	66.3	70.4	63 7	71.8	64.4
September	69.0	62.5	66.7	62.3	65.5	62.4	69.3	63.0	69.3	64.3	68.0	62.9
October	59.9	59.1	57.3	57.4	57 5	57.3	58.0	59.2	57.8	56.6	58.1	57.9
November	47.3	51.4	47 1	50.8	47 0	50.2	46.4	50.6	48.4	51.1	47.2	50.8
December	41.7	47.0	37.9	43.7	42 1	42.8	38.7	42.8	39 6	43.9	40.0	44.0
Mean	54.4	51 4	53.3	51 2	52.0	49.6	54.2	51.2	52.9	50.6	53 4	50 8

TABLE II.

NUMBER OF MICROSCOPICAL ORGANISMS (IN STANDARD UNITS* PER C. C.) IN THE WATER IN THE DISTRIBUTION PIPES. BOSTON, MASS.

Month.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	75	28	242	109	66	57	60	25	79	78	104	59
February	29	18	139	112	14	9	50	27	14	6	49	34
March	34	13	101	57	5	7	38	13	12	5	38	19
April	188	65	190	191	46	46	152	92	38	26	123	84
May	313	167	267	97	212	103	126	76	93	42	202	97
June	206	80	350	76	308	66	137	72	233	111	247	81
July	356	106	478	212	336	96	125	48	373	155	334	123
August	201	81	212	81	199	49	71	29	188	47	174	57
September	452	124	214	75	347	205	155	85	142	19	262	102
October	374	152	220	78	679	330	173	83	258	63	341	141
November	421	88	111	64	311	84	84	71	138	42	213	70
December	295	68	95	69	155	48	196	269	140	50	176	101
Mean	245	83	218	102	223	92	114	74	142	54	189	81

*One Standard Unit equals 400 square microns.

TABLE III.

AMOUNT OF AMORPHOUS MATTER (IN STANDARD UNITS* PER C. C.) IN THE WATER OF THE DISTRIBUTION PIPES, BOSTON, MASS.

MONTH.	1891.		1892.		1893.		1894.		1895.		Av. 1891-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	32	10	160	226	98	122	182	117	94	80	113	111
February	26	16	66	125	84	44	157	128	92	74	85	77
March	30	27	94	149	88	46	166	70	100	61	96	71
April	134	47	136	140	116	72	169	103	132	82	137	89
May	216	40	241	170	396	88	170	75	363	113	277	97
June	271	73	188	250	324	90	197	154	216	98	239	133
July	289	205	214	162	372	125	224	101	332	154	286	149
August	172	89	87	52	318	123	253	152	248	98	216	103
September	102	85	203	76	299	157	273	130	194	95	214	109
October	211	55	181	63	441	187	235	118	236	103	261	105
November	160	51	141	90	447	225	153	113	143	88	209	113
December	180	96	83	79	185	101	164	194	102	67	143	107
Mean	152	66	149	132	264	115	195	121	188	93	190	105

* One standard unit equals 400 square microns.

TABLE IV.

NUMBER OF BACTERIA PER C. C. IN THE WATER OF THE DISTRIBUTION PIPES, BOSTON, MASS.

Month.	1892.		1893.		1894.		1895.		Av. 1892-5	
	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.	Park Square.	Mattapan.
January	113	92	257	58	73	54	95	69	135	68
February	86	75	690	178	42	84	25	23	211	90
March	120	55	110	52	32	30	146	64	102	50
April	65	65	54	73	32	72	55	37	52	62
May	67	70	63	155	30	107	59	85	53	104
June	61	133	64	171	157	92	62	106	86	126
July	61	161	97	229	46	80	89	156	73	157
August	61	91	103	76	102	65	56	34	81	67
September	102	58	75	51	109	60	58	37	86	52
October	71	46	68	84	29	42	50	17	55	47
November	63	36	59	53	50	30	50	19	56	35
December	39	29	79	84	27	22	65	23	52	40
Mean	76	76	143	105	61	62	67	56	87	75

TABLE V.

NUMBER OF MICROSCOPICAL ORGANISMS, BACTERIA AND AMORPHOUS MATTER IN MYSTIC RESERVOIR AND A TAP IN CHELSEA, MASS. 1890–1893.

Month.	Microscopical Organisms. (Number per c. c.)		Bacteria. (Number per c. c.)		Amorphous Matter. (Number of Units per c. c.)	
	Mystic Reservoir.	Tap in Chelsea.	Mystic Reservoir.	Tap in Chelsea.	Mystic Reservoir.	Tap in Chelsea.
January	233	190	1,712	1,375	429	145
February	79	46	5,500	6,651	426	78
March	1,367	913	539	399	183	41
April	12,796	5,385	566	214	221	61
May	7,667	6,845	107	152	296	196
June	1,684	967	137	94	401	419
July	659	367	122	400	426	266
August	1,164	715	975	840	175	140
September	1,251	483	370	341	203	216
October	543	155	301	218	278	71
November	392	272	118	412	357	84
December	481	235	1,829	894	408	105
Mean	2,360	1,381	1,023	999	317	152

DISCUSSION.

PROF. PORTER: I would like to ask if anything is known as to the effect of the speed of the current on the formation of these growths on the inside of pipe?

MR. WHIPPLE. We know only that where the current is very rapid we do not find them. Where there is no current at all we do not always find them, because food is not being carried to them. The most favorable condition is a gently flowing current, but we cannot give any figures such as the number of feet per second.

MR. FULLER. I would like to ask Mr. Whipple how much flushing is required to remove these growths, whether it is possible by ordinary flushing to remove them?

MR. WHIPPLE. I do not believe that the ordinary flushing would remove them. You have got to increase the current to such an extent that they are really broken from the sides of the pipe. They are very firmly attached, and they are extremely tough.

MR. CHACE. I think the Association is greatly indebted to Mr. Whipple, and to the Boston Water Works, not only for this paper,

but, in general, for their biological studies. I myself feel personally indebted for information I have obtained from the reports of the Boston Water Works. For example, I remember reading in a report a year or two ago that in the Boston water they found the organism Dynobrion very common in spring months, at the time the ice was breaking up, and that the prevalence of this organism produced a bad taste in the water. I immediately looked at the analysis of the waters of our Lakeville ponds to see if we had any there, and I found that it was quite numerous in the Assawompsett water, but not in the Elder's water, so I immediately discontinued drawing from one pond to the other in the month of March. That is one case in which I have received benefit from the work of Mr. Whipple and his associates, and I do not doubt others of you could tell similar experiences.

A MEMBER. I would like to ask Mr. Whipple if there is any coating which can be used to prevent those growths?

MR. WHIPPLE. That is something I cannot answer, but I propose some time to make experiments along that very line. We know a rough surface favors the growths of organisms, for it furnishes a good place for them to become attached; further than that I cannot say.

THE PRESIDENT. I would like to ask Mr. Whipple, if in his examinations he has had opportunity to see whether the difference is perceptible between the number of organisms present in surface water and ground water.

MR. WHIPPLE. I know, as I said, that in the town of Brookline and in the city of Newton, there are practically no organisms growing in the pipes; that is, I learn so from the superintendents. I have examined the pipes of half a dozen or more surface water supplies in various cities, and I have almost always found them; in fact, I think I have never failed to find them.

THE PRESIDENT. I don't know but the Newton and Brookline superintendents may have had examinations made as to whether there were really any organisms in the water pipes, but are you fully posted as to that?

MR. WHIPPLE. I once asked the superintendent of the Brookline Works particularly regarding that fact, and that is what he told me; and perhaps Mr. Whitney, if he is here, can answer for the Newton water.

The President. There is no one better aware than Mr. Whipple that to an ordinary observer, the water pipe might look entirely free from any organism whatever, while a biological examination would reveal the fact it was teeming with these organisms. Now, as long as we do not know that there was any microscopical examination of that ground water, I should feel assured that it was full of organisms, certainly to quite an extent.

Mr. Whipple. The organisms of which I have been speaking are not microscopical. They are quite easily seen by the naked eye. The large growths are fully a quarter of an inch long, and I don't think anybody would be likely to overlook them; that is, if he were looking for them.

WOONSOCKET WATER WORKS RESERVOIR AND DAM NO. 3.

BY BYRON I. COOK, SUPERINTENDENT, WOONSOCKET, R. I.

[*Read Sept.* 9, 1897.]

Reservoir No. 3, of the Woonsocket Water Works, is situated in the towns of North Smithfield and Smithfield, five miles from the city of Woonsocket, and two and one-half miles from the pumping station on the Crook Fall brook, the same that supplies Reservoirs Nos. 1 and 2. The pumping station is located at Reservoir No. 1, No. 2 being about 1,000 feet up stream from No. 1. The storage capacity of Reservoirs Nos. 1 and 2 is 52,000,000 gallons, with a water-shed of 7.9 square miles. This was insufficient in a dry season, with an average daily consumption of 1,000,000 gallons, and the year previous to the completion of Reservoir No. 3 the city came very near suffering a water famine. Although warned by the Water Board of the necessity of additional storage, it was not until unwatered streets became unbearable from dust, drinking fountains dry, lawn hose useless, and the public out of sorts, that an appropriation was made for the necessary surveys, and purchase of land. (I will say right here, if any Superintendent is ever so unfortunate as to be obliged to ask the water consumers to economize in the use of water on account of short supply or accident, that I hardly think that his request will be complied with to any extent; the only curtailment will be the consumption directly under his supervision, such as drinking fountains, etc. Unless the water consumers of other cities and towns are different than those of Woonsocket, the only one to turn to for aid will be the weather man, and I hope he will help you out as he did in our case.)

Surveys for the proposed reservoir and dam were commenced early in 1894, and during the spring negotiations were commenced for the necessary real estate. Of course land values had advanced in the vicinity of the proposed site. Abandoned farming land was valued as much as corner lots in a flourishing town. It became necessary

to ask the Legislature for an "Act of Condemnation." This was granted at its May session, 1894. All parties interested were settled with, out of court, except two.

The law of Rhode Island grants the right to parties owning land taken under an act of condemnation to have their damages assessed by a jury, and it is surprising the difference of opinion of the men that comprise the jury, of the value of real estate. In one suit for a tract of 50 acres, I was told by one of the jurymen after the trial, that upon retiring to the jury room after the testimony had been submitted, and before the case had been discussed, each man gave his opinion as to the amount of the award. The highest was $8,000, lowest, $900; verdict, $2,800.

The reservoir flows an area of 197 acres. Its greatest depth is 16 feet; average depth, 9 feet; storage capacity, 529,000,000 gallons. Its elevation is 323 feet above tide water, and 167 feet above Reservoir No. 1. It has a water-shed of 1,944 acres of abandoned farming and wood land. Only two farms are under cultivation. The total population of the water-shed in 1895 was 14. Sufficient land was purchased to control the shores of the reservoir, the adjoining ownership at the nearest point being 100 feet from the flowage line, and on the north side, where the shed is the steepest, the land was purchased 1,000 to 1,500 feet from the flowage line.

The reservoir site was cleared of all brush and trees and thoroughly burned over. An estimate was made of the probable cost of removing the soil, and the expense was more than the city could afford. Another consideration entered into the outlay. The water is carried from Reservoir No. 3 to No. 2 in the open brook between the two. The brook has two large tributaries. These drain large swamp areas. It would have been necessary to have drained these swamps if the full value was to have been received from the expense of the removal of the soil in the reservoir. With the progress that has been made in the past few years with filtration of drinking waters, it was considered advisable to investigate the subject before making any large outlay in draining the swamp land.

The dam is located at the easterly side of the reservoir, and was built by contract. It is at present 1,300 feet long, 36 feet wide at top, and 28 feet high at its greatest height. The dam is so designed that when additional storage is required it can be raised 6 feet, increasing the area flowed to 240 acres, with a holding capacity of

875,000,000 gallons, the estimated yield of the water-shed. The dam is built of earth, with a core wall of concrete and 2-inch spruce sheeting. A spillway or overflow, 25 feet in width and 5 feet high, is located in the dam near the southerly end, and is built of granite. The up stream embankment is sloped 2 to 1, and rip-rapped with cobbles not less than 6 inches in diameter. The down stream embankment is sloped 1½ to 1, and is dressed with loam. Two effluent pipes, 20 inches in diameter, placed 3 feet on centers, pass through the dam near the spillway and are encased in concrete. These pipes are 16 feet below the flowage line, and draw the water only at that height. Four 20-inch Chapman valves are placed on the effluent pipes at the down stream end, and are placed 30 inches apart. These valves are flanged and bolted to the effluent pipes. The upper two are always open, the lower set controlling the flow of water. This set, in case of repairs, can be unbolted and passed out under the gate house through an archway, this archway at present being filled with a 12-inch wall.

The material underlying the core wall is of hard pan. Soundings 15 feet below the bottom of the core wall did not reach the ledge. The average depth of the core wall below the original surface of the ground is 15 feet. If it had required it, a single row of hard pine sheeting, 6x12 inches, would have been driven under the center of the core wall.

The core wall is 7 feet wide at the bottom and 3 feet wide at the top. It is composed of one part Rosendale cement, two parts coarse sharp sand, and four parts broken stone, screened to pass a 2½ inch mesh. It was laid in layers of 8 inches and rammed. It extends from the south end of the dam 550 feet, where it is joined to the 2-inch spruce sheeting. The up stream side is plastered with cement.

The 2-inch spruce sheeting, tongued and grooved, 20 feet long, extends from the core wall the remaining portion of the dam. It is footed into 12 inches of concrete. The excavation for the sheeting was refilled with selected material and puddled.

The embankments are composed of blue marl and gravel. The material for the up stream embankment being selected, all material was laid in layers of 4 inches and immersed with water. The constant passing and re-passing of the carts was sufficient to compact the material without the use of a roller.

The spillway was of granite and classed as broken ashler. The steps were of granite, fine pointed on face and top. The coping was fine pointed on face, and peen hammered on top. The steps and coping were laid in Portland cement.

The spillway between the core wall and the up stream shoulder of the embankment was paved with selected stone, not less than 1 foot in thickness.

The spillway apron was laid with large flat stones, weighing not less than 2,000 pounds, laid on concrete and thoroughly grouted, extending 80 feet from spillway steps. In front of effluent pipes an apron of hard pine 6x8 inches, 20 feet long, joined the spillway apron. This apron was laid on concrete.

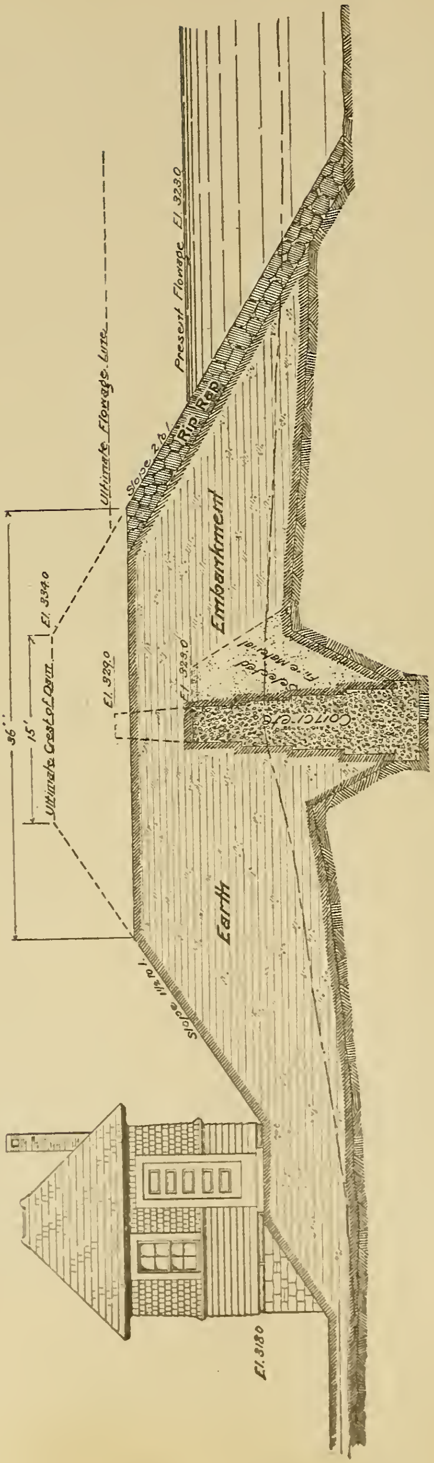
The gate house is of wood, 12x15 feet. A portion of the outside walls are shingled, the inside being finished with hard pine sheathing. All exposed parts of the foundation are of broken ashler. The gate house contains the necessary appliances for the operation of the gates, which were furnished by the Chapman Valve Company.

The Rosendale cement used was the Hoffman brand, and it required 4,474 barrels to complete the work. 1,348 samples were tested for tensile strength. 704 samples, 1 hour in air, 23 hours in water; minimum allowed, 50 pounds; average, 93 pounds; maximum, 177.5 pounds. 644 samples, 1 day in air, 6 days in water; minimum allowed, 70 pounds; average, 114.5 pounds; maximum, 197 pounds.

The Portland cement used was the Alsen brand. Number of barrels used, 40. Four samples were tested 1 hour in air, 23 hours in water; minimum allowed, 140 pounds; average, 210 pounds; maximum, 250 pounds. One day in air, 6 days in water; minimum allowed, 235 pounds; average, 305 pounds; maximum, 350 pounds. The cement was delivered at the dam site,—Rosendale $1.25 per barrel, Portland $3.20 per barrel.

The following is the cost of the different quantities taken from force account, and material used:

Grubbing and clearing dam site	$ 0.35	per cubic yard.
Wet excavation, including pumping	.82	" " "
Puddled earth embankment, (avg. haul 800 ft.)	.35	" " "
Rip-rapping up stream slope	.36	" " "
Loaming down stream slope	.31	" " "
Spillway paving	.36	" " "
Concrete, including cement	3.41	" " "
MASONRY.		
Broken Ashler, without cement	$ 25.59	per cubic yard.
Rubble, " "	4.64	" " "
Apron paving, " "	3.60	" " "
Gate house	582.36	



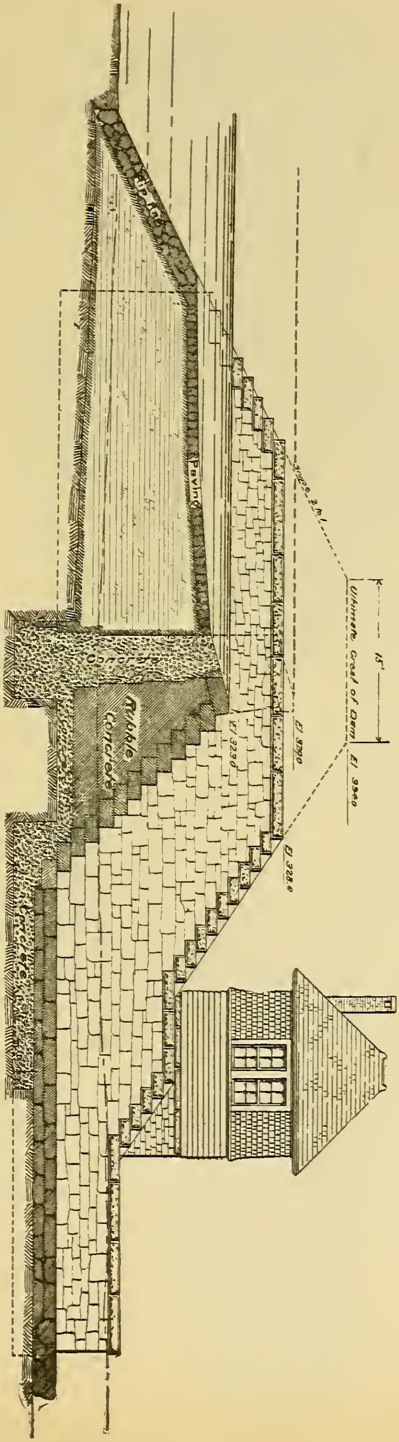
CROSS SECTION OF DAM.

-FACING SOUTH-

SCALE

0 1 2 3 4 5 6 7 8 9 10 FT.

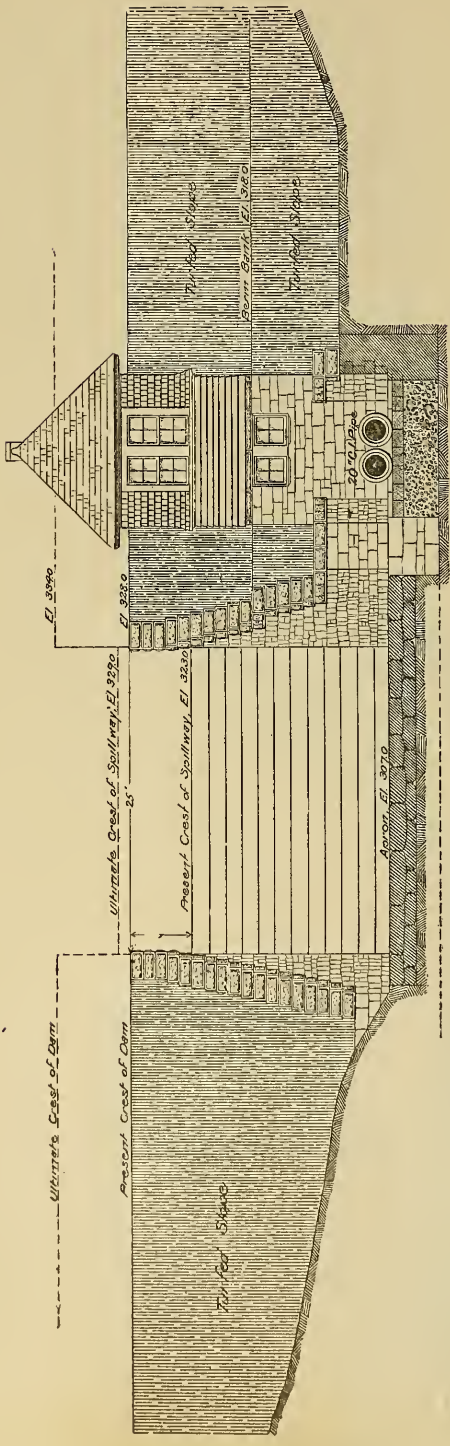
F. A. Caldwell, Del.



CROSS SECTION OF SPILLWAY.

SCALE

F.A. Caldwell Del.



ELEVATION
SPILLWAY & GATE HOUSE.

SCALE
0 1 2 3 4 5 6 7 8 9 10 FT
F. A. Caldwell Del.

DISCUSSION.

Mr. Stacey. I would like to ask if the water has been used by the city continuously since the reservoir was filled, in connection with the other water, and if so what has been the result of flowing the reservoir without the removal of any of the soil, and only removing the shrubbery and burning it over?

Mr. Cook. I will say, in reply to Mr. Stacey, that last season it was necessary to draw upon the reservoir. The water starts from the reservoir and runs two and a half miles in the brook, dropping about 167 feet. There has been no complaint, and it has been impossible to detect any trouble with the water at the pumping station. There is no question but it would have been better to have stripped the reservoir of the soil, but the expense was more than the city could stand; and, as I state in my paper, with the subject of filtration in the state in which it is at present, it was decided to wait and, if possible, to filter the water, in preference to draining the swamps and taking the soil from the reservoir.

The President. I would like to ask Mr. Cook if it would have added very much to the expense of this reservoir to have put the spill-way at either side, rather than in the portion of the main dam, where it is?

Mr. Cook. Yes sir, I think it would. And the character of the land each side was not so good for locating the spill-way. I can see Mr. Haskell's point. There is some question about locating a spill-way out in the dam, but where, as in this case, it is thoroughly incorporated in with the core wall.—You will observe on this section that the concrete wall and the backing for the spill-way steps are thoroughly bonded together.—I cannot see how there would be any trouble from leakage at that point. We have never discovered, since the reservoir was built, any leakage at all through the steps, or on them.

The President. I would also like to ask Mr. Cook if he observed during the summer any particular growths of organisms in the water, or has the State Board of Health made monthly analyses of the water and discovered anything?

Mr. Cook. Down here in Rhode Island we are not so particular about such things, or not so well fortified against them, as you are in Massachusetts. Our State Board of Health, so far as regards

water supplies, does very little. But I can say that I did discover in the reservoir, during the first season, a growth. We could not detect anything of the kind at the pumping station, however, and I account for that, as I have said before, by the fact of the water running so far and dropping, as it does, 167 feet, which gives it a chance to aerate itself. At one place within a thousand feet, the brook drops about 60 feet.

Mr. Stacey. If I understood Mr. Cook correctly, he stated that there were tributaries to the brook, draining a large area of swamp on two sides.

Mr. Cook. Yes, sir.

Mr. Stacey. And that has always been so; that is, they were tributary to the original supply.

Mr. Cook. Yes.

Mr. Stacey. And you never had any trouble from the water from this locality?

Mr. Cook. None whatever.

Mr. Stacey. The reason I am interested in this, is that we are in almost the same condition, although we stripped to a certain extent the shallow flowage of our reservoir, and we have 10 feet or more of water on everything that is not stripped. The city of Boston has been building reservoirs lately all around us, and the reservoirs have been put into use as soon as constructed, for the demand for water has kept up with the supply, and there has been a great deal of criticism on the part of some people, because in constructing our reservoir we did not thoroughly clean the bottom. But we have had the same idea Mr. Cook has, in regard to filtration. We looked at it in this way: That it was going to cost us a large amount of money to clean the basin of the reservoir, and we had to spend some money cleaning the shores, and while we might have a clean reservoir, one free from vegetable matter, which would be a very desirable thing, still we would have no defense against the water-shed, which was liable to contamination. By the time we were obliged to draw from that reservoir six or eight months in a year,—we are only obliged now to draw two or three, or possibly four months,—the development in filtration, both mechanical and the European system of sand filtration by irrigation, would have reached such a point it would warrant us in waiting. And it was a question in my mind, whether it was not a better plan to wait until we could adopt some

system of filtering the water as it goes to the consumer, rather than to spend about the same amount of money in cleaning up the comparatively small area of the basin which contains the water, which flows from an unprotected water-shed. We have used that water for three or four years, using it at the time of year when the water is at its best, in the winter and early spring months, and while our original supply was considered excellent, and is so shown by the analyses of the State Board of Health, we have failed to see where there was any difference between the water from the new reservoir and that from the old, at the season of the year when that water is used. Of course there is a great difference between the water at the surface and at the bottom. We took it three or four feet from the top, and we couldn't see any difference either in the color or in the organisms contained in the water.

The President. I would like to ask Mr. Cook if the character of the bed of this reservoir was sandy, or whether there were muddy areas which had quite a considerable amount of soil and muck?

Mr. Cook. The greater portion of the reservoir flowed was of a swampy character. It would have been necessary to have gone to a considerable depth in stripping the soil off the reservoir to have taken all the vegetable matter. The muck in some places was 3 to 4 feet deep, for 50 to 75 feet each side of the channel of the brook where it passed through the swamp.

The President. I would like to say a few words myself in connection with this matter of cleaning reservoirs. Where a city is putting in a large reservoir, it is a question of great importance. One thing is settled, that we must have purer water than we have been furnishing in the past. The best way to get it is a question which is to-day receiving a large amount of careful study, and there is quite a good deal of difference of opinion among Water Works men as to how to arrive at that result. Boston has perhaps made the greatest effort to purify the basins, where they were starting in for a new water supply, that has been made in the country, and the result has not yet demonstrated that the expenditure of money in that direction can be considered to be the best expenditure which is possible. It is a well known fact, as appears from the reports that the State Board of Health have given of the quality of the water in these cleared reservoirs, that it does not come up to the standard we ought to apply when we talk about giving pure water. There

are times in the year when there are organisms existing in these reservoirs to a greater amount than is desirable, and certainly to such an extent that I should expect to hear from some of our water takers, if we were supplying them with the water.

Now, there is this which can be said in favor of cleaning a reservoir. We all will readily admit that soil and muck, and every substance of that character in a reservoir, favors the growth of organisms, and forms an element from which a great deal of trouble is to be apprehended. But we also know that in former years there was no attempt made to purify water in this way, and we do know that from year to year the basins have improved, so that, varying according to the character of the reservoir, usually within a period of ten years, ponds have been brought to a condition by natural causes that has pretty fairly paralleled what we find in these new cleared reservoirs.

Furthermore, let us consider what is the practical condition of a pond, we will say in ten years after it has been cleared and filled? All these reservoirs have a large amount of water flowing into them in streams, which carry a good deal of soil and other things, depending very much on the character of the water-sheds through which the streams pass. Now allowing that we start with a perfectly clean pond, as is supposed now to be the very best. From year to year all of this floating debris and soil and everything that comes down, is going to be deposited upon the bed of that pond, and it seems to me that experience is going to show us that the natural causes have intervened to render the bed of a pond that has been cleaned almost in the condition in which it formerly was. Now, we haven't had an opportunity to thoroughly demonstrate that, but indications, as I look at them, point to our arriving at that result. Well, if that result is to be reached, it does seem as though this great expenditure of money that we are forced to go to to clean out the bed of a reservoir, is perhaps unwise. As Mr. Cook says, we undoubtedly are going to have filtration as the practical method of purification of surface water supplies, and it looks to me that, granting the water may be somewhat worse in a basin that has not been cleaned, the final result after filtration and purification is going to be practically the same. And it does seem, as both Mr. Cook and Mr. Stacey have said, that it is a question which requires quite a little deliberation before we spend too much money in cleaning out reservoirs.

Mr. Cook. Mr. Haskell's remarks have been just in the line of the arguments which were used in our case. As I have said, the trouble with the Woonsocket water is the color. If we had gone to the expense of cleaning our reservoir, 197 acres, at an expenditure of not less than $100,000, we should not have been any better off, so far as color is concerned, than we are with the reservoir in its present state. Passing as it does down through quite a large area of swamp, our water would have been just as high colored when we received it at our pumping station as when it left the reservoir, and we considered that in view of the progress which is being made in filtration, it would be better to put our money into a filter plant, either mechanical or sand, rather than into cleaning the reservoir.

Mr. Fuller. I would like to ask Mr. Cook if he made any estimate of the expense of filtering the supply?

Mr. Cook. We did not to any great extent. It is my opinion that a mechanical filter, sufficiently large for our use at the present time, can be put in for about $50,000. The cost of sand filtration we didn't go into. I believe the time is coming when most of the water supplies in New England have got to be filtered, for the people are going to demand it.

Mr. Chace. I suppose the members are aware that ordinary filtration does not remove color. In order to remove the brown color from swamp water, the process of filtration would have to be supplemented by the use of some kind of a precipitant like alum, and the State Board of Health have condemned that, as an excessive amount of alum is likely to be injurious.

The President. I think when we come to the question of color in water we are opening up quite a question. The qualities that give color to water are very distinct, and sometimes color in water does not mean it is bad water at all. There may be a certain amount of carbon in the earth that would color a water very highly, but would not injure the quality of it at all. The principal cause of color in this reservoir is probably the swamps in the water-shed. It might be possible that a very small swamp might have added very much to the color. I have seen water taken from a brook just below a cedar swamp where the color ran up as high as 700. Well, you can readily see how that is going to affect the color in the pond, where the color ought to be probably about .040. Now, if in this water-shed there was an area of 30 acres, and a cedar swamp the

water from which was colored up to 700 at certain times of the year, the remaining portion of that entire area might be down to a very fine color, and still the water in the reservoir be highly colored. Our State Board of Health in Massachusetts think that there should not be any color in the water. Of course that is very desirable, but it is going to be very difficult to get all the color out, and when you get down to .070 it is not perceptible at all in a tumbler. I myself feel that it is sufficiently fine to draw the color line to a point where, when a person picks up a tumbler of water, the water looks colorless. Well, at .070 there are very few who would notice the color, particularly if they were quite thirsty.

I think that there would be no difficulty in bringing the water in the Woonsocket reservoir down certainly to an average of .070, for I have done some careful work in areas that are something like that there, and I have found no difficulty, where we had a color of 300, in reducing it down to .040 by a system of drains running around the portions of the water-shed that the color came from, eliminating all that portion of the water-shed which was above those low figures and stopping the water from running down into the swamp and getting the color. I don't imagine that it would be an item of very large expense to remove the color of the Woonsocket water down to .070. That is something which is going to attract a little attention in the future, the care we take of our water-sheds, for, although filtration may take everything out, it is very desirable not to get anything in. We want to start with the water just as pure as we can get it, and we want to do it in the cheapest way. The different methods have got to be carefully studied, and we are going to know more on this subject than we do now. One way to learn is to talk these things over, and get at the different ideas of the members about them.

Mr. Hazen. The question of color, of course, is an important question;—important, as our President has said, because of the color itself, and not because of any unhealthful property in the color. The coloring matter is something, perhaps, like that which gives color to coffee, and we certainly don't care to have our coffee as light colored as even the darkest of the waters. But it is pleasanter to have a colorless water on the table than a yellow water. It is a matter of taste. We like to have some of our drinks colored, but we like to have our water white.

The question of the removal of color by filtration is a difficult one. Passing water through sand in the ordinary course of filtration always removes some of the color. If the filtration is rapid and the sand layer is not very thick, the proportion of color removed is very small—hardly noticeable. In filtration through a thicker layer of sand and at a lower rate—as, for instance, in the Lawrence filter,—from one-half to one-third of the color of peaty waters is removed, seldom more. The proportion of color removed depends upon the character of the sand. A pure quartz, like the Berkshire sand, removes hardly any color, while some sands, containing a good deal of iron, aluminum or manganese, remove a very large proportion of the color. They may remove all of it for a short time and a large proportion of it for a long time. I had the pleasure last fall of visiting some filters in England for the supply of the city of Liverpool, where the sand had been in use for some thirty years. They were filtering a quite yellow water, and the proportion of color removed at the end of thirty years, without changing the sand, was from two-thirds to three-quarters of the total color of the water, so that the effluent from a very highly colored supply was practically colorless. This sand was very dark colored, almost black, and had an extraordinary property of getting rid of the color. The city of Liverpool has recently constructed some other filters, in which another kind of sand was used which it was thought would be better than that old sand, but it was found that it removed not more than a third of the color.

The color of peaty water can be removed by the use of alum. It takes more alum to remove the color than has been commonly supposed. I have been furnished with records of the amounts of alum actually used in removing colors from peaty waters during the last year, by members of this Association and by others, and I have been surprised at the large amount of alum which it is necessary practically to use to get rid of the color. In the waters of the middle states there is usually a considerable amount of lime carried in solution, which makes the waters hard, and this lime will decompose a large quantity of alum completely, so that almost any quantity that is required in water purification can be added to the water, and the decomposition will be complete, and the alum will be removed, and the sulphuric acid will be in the effluent as sulphate of lime. In many eastern waters, in New England waters particularly, there is

very little lime in solution, and with these waters it is not possible to add large quantities of alum without using up all the lime and leaving an excess of acid and a quantity of undecomposed alum which is objectionable. I have known cases of this kind where quite serious trouble has been caused by rendering the water acid.

A number of other means of removing color have been suggested as a substitute for alum. One of the earliest and most important of these was the Anderson process, in which the water was brought in contact with metallic iron, the idea being to oxidize the iron, forming ferric hydrate, which would do the same work in the water that the alum would do, but without the addition of the sulphuric acid to the water. This process has been in some cases apparently quite successful, but with New England waters it has been found that the iron will not be acted upon fast enough to make it a practical success. It is necessary to keep the water in contact with the iron in motion for so long a time as to make the cost practically out of the question. Recently there have been several schemes suggested for hastening this action by means of electric currents, and aluminum has been suggested to take the place of iron. These processes have been tried in an experimental way in a few cases, but I do not know that any practical results have been obtained from them as yet.

I can simply say that by the use of sand, particularly when a sand can be secure which has a peculiar power for removing color, it is possible to remove a great deal of the color, and in many cases enough can be removed so it will not be objectionable. When the water is very highly colored or filtering material of the peculiar quality is not obtainable, the only way in which to get rid of the color is to use some coagulant or its equivalent, and the best way of getting at that is one of the questions which is still under active discussion and investigation.

Mr. Fuller. I would like to ask Mr. Hazen if the matter that causes the peaty taste in water is the same which causes the color?

Mr. Hazen. So far as I know it is, Mr. Fuller. We certainly find the two things associated with each other and going together.

The President. I should like to ask Mr. Hazen if he has any information to furnish in relation to the relative expense of filtering a city's water supply by mechanical and sand filtration?

Mr. Hazen. The cost of mechanical, and also of sand filtration, depends altogether upon local conditions. In certain cases beds of

sand are found, which are exactly suited for sand filtration, right on the ground. If the places are far enough south so that open filters can be used, sand filters can be constructed very cheaply. In other cases there may not be a sand bank in a hundred miles, and covered filters may be necessary, and the cost will run up to several times the cost of mechanical filtration. The cost of mechanical filtration will also vary very much with what you require. The mechanical filters were formerly operated at the rate of 3 gallons per square foot of area per minute. Now they are running filters at a half or a third of that rate which means a very much larger area. Then it depends upon what is required in the way of a mechanical filter. Some mechanical filters are simply washed by a reverse current; others have stirring devices and other arrangements. If you are satisfied with the simplest apparatus, you can build a mechanical filter very cheaply indeed. But, on the other hand, if the best devices for stirring the sand and regulating the rate of flow, and so forth, are required, the cost of mechanical filters runs up considerably A three million gallon sand filtration plant, which I was interested in last year, and which was built by day labor for about 10 per cent. less than the lowest bid for a mechanical plant of the same capacity. The conditions there were very favorable. Under other conditions the comparison would not be at all the same.

SERVICE BOXES.

BY GEORGE A. STACEY, SUPERINTENDENT, MARLBORO, MASS.

[*Read Sept.* 9, 1897.]

The question of service boxes was brought up at one of our previous meetings, and it was suggested at that time, there being no discussion of the subject then owing to the lateness of the hour, that perhaps there might be some information of a practical nature which, if there was time at this meeting, might be brought out here by bringing up the subject again. It seems almost trivial to speak of a thing like that, but at the same time it is one of the many little things which goes to make up the great whole, and in regard to this, as to many other things, we are not all situated under the same conditions, and do not all think alike. This subject was brought to my mind in the first place by the occurrence several times of trouble in the winter on a cold night,—all our troubles come in a cold night, you know. Of course you go to the place and suppose everything is all right, so you can turn off the water and can get back to bed again, but you find some boy has smashed the box some time during the summer, or a stone has worked in somewhere, and the water can't be shut off. Now the trouble with gate boxes with me is from the displacement or the heaving of the box by frost, the ground being largely composed of hard-pan and clay, which expands to a very large extent in the winter and lifts the box. The gate box we have used has been in two sections, like the majority of the gate boxes, and the last kind which was used was the old Buffalo screw box. When they first came out the thread on the screw was fitted comparatively close. Shortly after that it was made larger in the thread on the upper section, and as small as possible on the lower section, so as to give the box as much leeway to come and go as possible. Well, if they had about six times as much as they have now it wouldn't be any too much. The trouble is the box comes up, and we have to drive it down again,—we have to drive the whole box down. If the bottom comes up, when you drive it

down you will find that the tendency of the material is to work under the box, and if there is a stone anywhere in the vicinity I believe it comes to that place to get up in there. And while you can take some water and get out the soft material by churning it up and down, the stone will not go out, but will stay in there and get in its work. Then we find in boxes where the wrenches go clear down to the stop and waste, that the tops are broken, that they are not heavy enough to stand the work of the small boy, or a coal wagon, or the other things we have to contend with, and the whole thing is disarranged in time by frost, and the boys, and the general hard usage which such a thing gets.

Now in concrete sidewalks, and in places where there is perfect drainage of the land, these troubles would not exist, and in some places in our city where we have concrete walks, and we have a large number of them, we don't have any trouble in this way. But in other sections of the city we will find a box standing up from the concrete walk in the spring of the year sometimes three inches. Of course in the main streets this does not occur, for the boxes are forced down by the travel over them.

My idea of a gate box is that it should be made of two parts, a telescope pattern, the top and bottom entirely separated, as far as any mechanical connection is concerned. The bottom should be of sufficient size to withstand an upward thrust, and fit close enough around the stop and waste and pipe to exclude the possibility of any material getting around it. The top should be perfectly free, with a very generous flange, and with a cover sunk into it so it will stand any ordinary hard usage. When you can get a box of that kind and set it, you will be pretty sure to find it in the same condition in which you set it two or three years afterwards. The rod should extend enough so you can get a wrench onto it, and it must be heavy enough so that corrosion will not weaken it, so that it will not twist off and leave you in worse shape. You must have it sufficiently heavy to compensate for the corrosion which will take place, and which, as a general thing, takes place right in the stop-cock. If the two parts of the box are not separated, so the top section can come and go freely without disturbing the base, then a stone or other material is likely to get in so that even with your rod up where you can get at it, you are not sure of shutting the stop-cock off. It looks to me as though we might devise a box that

will exclude the material from the bottom, which will give the top a chance to rise and fall, and which can be driven down by a man going along the street, without disturbing the bottom of the box.

I have seen one or two boxes which have been brought here by some of the members, one of which comes very close to my idea of what a box should be, except that for use in our soil the top section, which is telescoped onto the lower section, would have to be longer than it is, for it must extend below the frost line in a severe winter. We have a winter once in eight or ten years which is colder than other winters, when we find the frost three and a half to four feet deep. Of course in filled ground it will go down six feet, but that is not a fair ordinary condition. We often go through frost three and a half feet on the south side of a street, and on the north side in our town (I don't know how it is elsewhere) there is certainly from six inches to a foot difference between the depth of the frost there and on the south side of the street. One objection I would have to the box to which I refer is that it simply stands on top of the pipe, and there is no protection against anything working up into the box, and there is no foot on it to give it stability. It should have a flange much larger than that has, so it would have as much holding power as the large base does on the regular gate box. My idea of the stop would be to have the same thing that we have on our mains, a first class gate, with a rod of some substance which would not corrode, and which would give you a chance to put a wrench on it and turn it as easily as you can a faucet. I would like to hear from some of the other members, as to whether they have had any trouble with their service boxes. If I have had it all I won't say anything more about it, but will try to bear it.

Mr. Gilbert. I would like to ask Mr. Stacey if he believes it is the best plan to have a rod attached to the shut-off in the sidewalk? I understood him to say that his were arranged in that way.

Mr. Stacey. No, sir, I haven't got a rod. I put in two, but I came to the conclusion I wouldn't put in any more. If I put in a rod again I don't think it will be less than seven-eighths of an inch in diameter. (Laughter.)

Mr. Gilbert. I would say I never put in but one, and I broke that the first time I tried to use it. Of course we all have trouble enough with the service boxes, and I never have found one yet which I thought was just the right thing. I know the common

Buffalo box in some respects is very good, but the tops, I think, are not made right. If they come up to the top of the ground, as we sometimes use snow plows in our town they are pretty sure to scrape the top off, or if something else heavy runs over them they are pretty sure to be broken, and the small boy, of course, takes delight in taking off the top and filling up the box with stones. It seems to me that some of these manufacturers of water works goods ought to put a little thought upon this subject. Perhaps they may think it is a small thing, but it would save us lots of trouble if they would get us up the right kind of a box. I think, in the first place, they are made too light, so they break too easily. If a wagon runs onto them, with any kind of a load, it is pretty sure to break them, to crush them, and there are many places around the town where that is happening, and we have lots of trouble by their breaking. I have noticed a box in some cities; I never could seem to find out where it was made, or exactly how it was made, only as I could judge from seeing it in the sidewalk; I have noticed it has a large nut in the center, and the top is set in in some way. It seems to me to be a better box than I have ever used, and I would like to inquire if anyone here has ever used a box of that description, and can give me some information about it.

Mr. Fish. I have had some experience with boxes, and have tried a good many of them. The conditions in which we use them are perhaps the worst existing in any place you can find in the country. I have found nothing so serviceable as a good heavy 4-inch pipe, a heavy soil pipe, cut off to the proper length and fitted over the pipe, with a cap extending down four or five inches, so it will not be jarred off or worked off, but will lift off freely by getting hold of it. I have had some experience with rods attached to the cocks, and I never put one on unless we had what we call a reverse-cock; that is a plug going in from the bottom, so any pressure coming on top of the rod would loosen it. Then a light rod will be serviceable and work well. This plug is kept in place by the water under the bottom. It is large, fully an inch on the bottom, which gives a water pressure which keeps it up in place, and it will never wedge or get tight, so you can easily loosen it and turn it. As I say, we have got right down to using plain pipe almost entirely.

Mr. Gilbert. I have been told by some of the manufacturers of such goods that a box such as I describe would be too expensive.

Now a matter of fifty cents on a sidewalk box is nothing, if they will only give us a better box than these common cheap boxes. The cheapest articles are not always the cheapest in one sense of the word, and I would be willing to pay a proper price for a good service box if I could find one.

Mr. Fuller. If we had room at our headquarters, I think it would be a good thing to have a collection of all sorts of service boxes, with a statement of where they are used, and what they cost, and how they are made, and so forth. And, in connection with that, I think it would be a good thing to have samples of different kinds of service pipes, properly labelled as to the length of time they had been in, the conditions of the soil in which they had been placed, and so on. Last night we had a very interesting talk in regard to the different kinds of service pipes, and if the members would contribute samples that they had taken out, and they could be labelled properly, it seems to me it would make a very interesting collection.

[Mr. Stacey brought into the hall a service box belonging to Mr. Holden, which he explained to the convention as meeting his views in some respects, while criticising it in others.]

Mr. Chace. I would not have a center rod on any account. If I shut off a man's water because he doesn't pay his bill, I should expect with that thing there he would find some way to take the cap off and turn the water on himself.

SERVICE PIPES DEFECTS AND THE REMEDY.

BY GEORGE F. CHACE, SUPT., TAUNTON, MASS.

[*Read Sept.* 8, 1897.]

It may be doubted whether the ideal service pipe has yet been found. No material or combination of materials has thus far proved an unqualified success.

The discussions of this topic at previous meetings of the Association have disclosed the fact that the majority of Superintendents prefer lead for service pipes. Their second choice is cement-lined wrought iron pipe, with a goose neck lead connection between the iron and the corporation cock, for convenience in the fitting and adaptation to the practical difficulties of exact grade.

The obvious objection to lead is the haunting shadow of possible lead poisoning. Experience has, of course, shown that many waters do not act injuriously upon lead, a protective coating being soon formed. Other waters do dissolve the lead, and for such, lead service is unsafe. There is, to the cement-lined iron, an objection which leads me to state some of our Taunton difficulties, hoping to draw out from the experience of others a discussion which may lead to some practical good result.

Small iron pipes not only rust out soon and leak, but often become filled with rust and sediment, to an extent which lessens the flow of water, sometimes so much as to make a service practically useless. Lining the pipes with cement has not, in my experience, wholly removed the evil. However much pains may be taken with the lining, the cement at the connections and at such bends as may occur in the pipe becomes more or less broken, the water comes in contact with the iron, and there is also, between the bronze of the service cocks and the iron of the pipe, a galvanic action, which tends to fill the service cocks with rust and thus stop the passage of water. Formerly the couplings were lined as follows: two nickel plated brass thimbles, like the samples, were put together at their flanges, the inside forming a cylindrical ring for the flow of the

water, and the space between the outside of the thimbles and the inside of the couplings was filled with solder as far as the thread on each end of the coupling.

I have brought for exhibition a sample of a coupling thus prepared for use, and another sample of one taken out from a place where there had been complaint of poor service.

Having found, as will be seen by the rusty sample, such linings of the couplings to be apparently failures, we have abandoned the practice of lining couplings, and use them plain.

I have prepared a record of our work on poor services, for the years beginning with 1892 and ending with 1896. At the end of our financial year, Nov. 30, 1892, we had in use in Taunton, 3,507 services. We had, during the year, 109 cases of poor supply, about 3.1 per cent of the whole number of services.

The majority of these cases were remedied by disconnecting at the stop-and-waste in the cellar, and running a large wire through the service pipe as far as the service cock, and often as far as the corporation cock. When this method failed to make the service clear, the work of the wire was followed by the use of a small pipe of $\frac{1}{4}$ inch internal diameter. If, on account of the excessively bad condition of the service pipe, or because of too many bends, the above method was fruitless, then the last resort was to dig up the service and clean out the pipe, or in one or two cases, to replace with a new pipe. Of the 109 cases of poor service in 1892, there were 20 where the corporations had to be cleared out, and 8 cases where the whole service was dug up, making in all 28 instances of digging up a part or the whole of a service.

39	of these services	had been	set	15 years or more.
75	"	"	"	10 " "
8	"	"	"	only 5 years.
1	"	"	"	less than one year.

Three times, during 1891 and 1892, services were stopped by large eels; twice they plugged up the corporation, and one filled the whole eighteen inches of the lead connection.

They were all alive when found, about three-quarters of an inch in diameter, and from a foot to a foot and one-half long.

The meshes of the screens in use would not allow the passage of a small lead pencil, and the eels could not have passed the valves of the Gaskill pumps. They must have got in when small and

grown in the pipes. It is not surprising that small pipes should fill up in the course of ten or fifteen years, but it would not seem to me that they ought to fill up in five years.

I felt much disturbed during the winter of 1892 to find that we were having so much complaint of poor service. I thought then that one cause of the filling was to be found in the fact that Taunton city water was imperfectly filtered—mixed river and ground water, which contained considerable iron. This gave rise to a growth of crenothrix, which, when in mass, not only has the appearance and effect of iron rust, but is somewhat gummy, and thus readily clogs up the pipes.

We were then in the midst of our work on the Lakeville extension for a new water supply. I therefore hoped that when we should have in use the new supply from the Lakeville ponds we should have less trouble with the services. My hopes were the stronger because the services which we had to clean contained not simply rust but a great deal of sticky muck.

In order to show what the actual facts have been I will give the records of 1893, 1894, 1895 and 1896 in regard to poor services in tabulated form.

Financial year ending November 30, 1893:

Number of corporations dug up	8
Number of whole services dug up	20
Number of services cleaned out with wire	48
Number of services replaced by new service pipe	1
Total number poor services	77

Financial year ending November 30, 1894:

Number of corporations dug up	1
Number of whole services dug up	10
Number of services cleaned out with wire	83
Total number poor services	94

On April 5, 1894, the Lakeville water was first supplied to the city. For about two months we still continued to use the old filter basin during the night pumping, but since that time nothing but Lakeville water has been used, except for about one day a year, when we clean the gate-house at Elder's.

Financial year ending November 30, 1895:

Number of corporations dug up	1
Number of whole services dug up	1
Number of services cleaned out with wire	30
Total number of poor services	32

Financial year ending November 30, 1896:

Number of corporations dug up	0
Number of whole services dug up	0
Number of services cleaned out with wire	26
Total number of poor services	26

The whole number of services in use November 30, 1896, was 3,955, so that the number of poor services was less than .7 of one per cent, against 3.1 per cent in 1892. Moreover, of these 26 cases of poor service—

11	had	been set	15	years	or more.
3	"	"	20	"	"
21	"	"	10	"	"
1	"	"	4	"	"

This last was on a street where the main had been changed during the year from a 6-inch to a 12-inch pipe, and the service had been supplied during the change through an unlined 2-inch pipe, laid temporarily along the curb. I feel justified from these facts in the belief that the character of the water supply has much to do with the condition of service pipes.

There may even be some disadvantage in using a very pure water. The total average amount of solid matter in the water of Elder's Pond, Lakeville, in 1895 was 2.88 parts per 100,000, while in the filter basin during the same year it was 4.89, and in the river 5.24.

In Taunton, the house cold water pipes are mostly unlined wrought iron. I have known these pipes, since we have used Lakeville water, to be badly rusted in two years. I infer that the less pure water of the past formed a coating on the inside of the iron pipes, thus preventing further corrosion, while the present pure water keeps rusting the exposed surface, especially where there is a constant change of temperature from pipes, through a part of

their course, passing near the furnace in the cellar or near hot water pipes.

I have come to believe that the best service pipe at present in the market is tin-lined iron pipe. It costs more than cement-lined iron, or than lead-lined iron.

But for all-round use, for waters good and bad, soft or hard, it is free from the peril of lead, and it may be hoped that experience will show it to be more trustworthy than cement-lined iron. Time and experience may reduce the cost of the tin-lined iron. I have begun to use it and expect success.

The defects of service pipes are known to all. The remedy seems to be: get the best water supply possible, watch the market for every improvement in service pipes, study your own supply and defects of service, and, by experiment and consultation with brother Superintendents, learn the way to progress and to ultimate perfection.

DISCUSSION.

Mr. Hawley. We have been having in Atlantic City very much the same experience as the gentleman who has just read his paper has had. I have here a piece of half-inch pipe, which was galvanized once; it is solid now with the accumulations of rust in the past ten years. When the works were first constructed, in 1882, they began to use lead pipe. This was expensive and the people objected to the cost, and the company finally began using galvanized pipe, and its use has been continued until within the past year. During the past year we have renewed 150 galvanized services. It is impossible to clean this pipe after the rust accumulates. We have a total of about 3,700 services, and out of that number we have renewed, as I have said, 150 the past year from curb to main. We have been looking about for something to take the place of galvanized pipe, and I have finally come to exactly the same conclusion which the gentleman who has just read the paper has reached, that tin-lined iron pipe is the best thing on the market for the money. We cannot use lead, because our water is partly swamp water, a considerable amount of vegetable matter in it, which seems to attack the lead, and the Board of Health won't allow us to use it. We are using tin-lined pipe galvanized on the

outside. The lining has proved satisfactory, whereas the coating on the outside of the pipe has not.

Mr. Fish. I would like to ask the gentleman if there are electric cars in his city?

Mr. Hawley. In Atlantic City we have an electric railroad crossing all of our cross-mains, and running parallel to the pipes of the two different systems on Atlantic avenue. We have had absolutely no trouble from electrolysis. The electric road is controlled by the Pennsylvania Railroad Company, and the rails are thoroughly bonded and there is a return conduit to the power station, and this may account for our having no trouble. The only case of electrolysis we have had was on the service which supplied the railroad company's car barn, and at that point the rails, I believe, are not bonded as they are elsewhere. As to the effect of brass and iron, or lead and brass connections in our street connections, we have had no trouble at all.

Mr. Chace. We have electric cars in our city, and I had some fear of electrolysis. Fortunately we had an opportunity two years ago to see whether anything was happening or not, because along two streets where the electric cars run we took up old mains and replaced them with larger ones, and I took pains to look to see if I could find any evidence of any injury to the services or the mains. I am happy to say nothing of the kind was found. The cars had not been running very long, not more than two or three years.

Mr. Fish. I have had some experience in this direction. I have been putting in galvanized iron services for thirty years. I have pipes which have been in now for thirty years, and they are still in pretty good condition. I have others that haven't been in three years, which have badly filled up and rusted and have holes in them. In some cases mains have been corroded to that extent that they have burst, and we have had to take them up, and in such cases I have noticed the services have been badly affected. This condition I have attributed to electrolysis. You won't find much trouble in dry ground, but in moist ground electrolysis has a bad effect on the services and the mains. The service pipes will feel it first.

Mr. Cook. I would like to inquire how far this was from the power house.

Mr. Fish. In one case it was about 1,500 feet. I have had cases in pipe entirely off the line, on a side street, at least 1,000

feet from the street car tracks. The worst trouble I have noticed is where an iron pipe is conected with brass; in fact, that makes a galvanic action of its own.

Mr. Bancroft. I would like to ask Mr. Chace if he has found more defective services on low ground or on high ground, or if he has found them equally distributed?

Mr. Chace. I think there has been more trouble in wet ground, but some were noted on high ground.

Mr. Gilbert. I think this is a question we are all very much interested in, and it is rather a hard one to solve. Now, in my experience (and, of course, all of us have had more or less trouble from the filling up of pipes) it has not always been the pipe which filled up first. The fittings, the corporation cock at the main, and also the shut-off in the sidewalk, I have found to be the first to fill up. I think if we would all use a corporation which is finished on the inside and made perfectly smooth, and also a smooth shut-off at the sidewalk, we should do away with a great deal of this trouble. I know that pipe will fill up, as a general thing, in from about 10 to 15 years, but I think if we could avoid trouble in the connections they might last perhaps considerably longer.

More than half of our services are metered where the pipe comes through from the ground into the cellar, and I find considerable trouble with the connections, in the shut-off or between the shut-off and the meter. When a complaint comes to me that a service pipe is not doing its duty, I always look there first. I disconnect the meter, and very often I find the shut-off all filled up. And I might say in four cases out of five there wouldn't be a hole through as large as the small end of a pipe stem. Of course the service wouldn't be very satisfactory with the fittings filled up like that. After clearing this out, if we don't get the proper pressure, then we run a wire through, as has been stated here by the gentleman in his paper, as far as the shut-off at the sidewalk and clear it there; and if that does not produce the right effect we dig it up at the main, and there in most every case I find the same difficulty that I found back of the meter in the cellar, that the connection has filled up.

We have used cement-lined service pipe, and that, as we all know, will not fill up as quickly as an iron pipe. We never have used galvanized pipes at all. We have laid some lead, but, as the gentleman from Atlantic City has said, so our Board of Health would

not allow us to lay it. We did lay a litttle of the lead-lined pipe, but they would not allow us to lay that, and so we have continued with the cement-lined pipe. Now I am very careful about the corporation, and I have the sidewalk cock made with a full finished hole also. Many people, where they have their piping in the cellar done outside of the water works department, use these cheap shut-offs which have an oblong hole through them and unfinished, and there is no part of the service pipes which will fill up so quickly. In my opinion we should be very careful to use nothing for a shut-off or corporation that hasn't a finished surface on the inside.

Mr. Richards. Some 12 or 15 years ago I investigated this matter of service pipe carefully, and embodied the result of the investigation in a paper which I read before the Association. The conclusion I arrived at then was that lead was the best and the cheapest service pipe, except in exceptional waters; and I have seen no reason yet to alter that determination. As regards tin-lined iron pipe, the pipe which was made at that day under a patented process was made by expanding a tube of tin inside the iron pipe. I don't know how it is made at present.* But the result of the use of that was that water penetrated around the end of the tin tube, rust formed between the tin and the iron, compressed the tin tube in the pipe, and filled it up. The conclusion I arrived at then was that tin-lined iron would not do. We have used lead continuously with very satisfactory results.

Mr. Bancroft. I remember but three cases where service pipes on our works have been clogged up. The first one was a long iron cement-lined pipe—I think the service was about 150 feet in length. This became clogged and was cleaned out with a wire, as has been described, but it closed up again. The pipe was then taken out and was found to be nearly filled, while the sidewalk cock and the corporation were entirely free. A lead-lined service pipe was laid in the place of this cement-lined pipe, and after a period of possibly a year, complaints came in again that there was no flow of water through the service. That was dug up and was found in about the same condition that the cement-lined pipe was in. Those were both three-quarter inch pipes—that is, the cement pipe was one inch lined

*The manufacturer of tin-lined pipe desires the editors to say that the pipe as at present manufactured is superior to that referred to.—*Editors*.

with cement, making a three-quarter pipe. I took out the lead-lined pipe and put in an inch and a quarter galvanized pipe, thinking I would have a pipe large enough so as to allow room for some filling up. That pipe has been in service now about two years, and we have had no complaints from it. It is on about the lowest ground we have, I think, in fact, it is the lowest service we have.

Another pipe, which was of lead, a long service, as I remember it, was about 200 feet, has been closed up and cleaned twice, I think, by the use of the wire, and it is still in service.

Mr. Fish. Two years ago, I think it was, some member of this Association made a statement of an experience of his, where he had put in three service pipes about the same time, side by side, one of which filled up and gave a great deal of trouble, while the other two remained perfectly clear. These pipes were neighbors, within about 200 feet of each other, and were all galvanized pipes. I think it was the gentleman from Burlington who made the statement, and he raised the question whether there was not something in the quality of the iron itself which might account for the results. It seemed a very strange thing to me at that time, and it did not agree with my experience. I would like to know if any gentleman here has thought anything more of the subject since then, or has ascertained whether one kind of iron has a different capacity for filling up than another. The gentleman from Burlington stated his experience very clearly, but there was not much discussion of the matter at that time, because we were about adjourning for dinner, which seemed to be more important just then than closed up pipes.

Mr. Gilbert. A year ago last winter I had a service which commenced to leak, and I had it dug up near the house, and found it leaked there. We put in a new shut-off, and still it kept leaking, and we finally dug up the whole service from the house to the street. The pipe had been laid about five years, and I found it was full of holes from one end to the other. It was laid in low ground, where it was wet nearly the year round, but it was not on any street where electricity could have had anything to do with it at all. I could account for its condition in no other way than by laying it to the kind of iron of which the pipe was made.

Mr. Fish. I think the gentleman may have been mistaken in his conclusion that electricity could not have had anything to do with it. It is not necessary that a pipe shall be near a line of street

cars in order to be affected by the electric current. If the cars run on the line of a main pipe anywhere, it may take an offset and follow the main pipe around. I have known cases where that has happened. I do not think there is much trouble to be feared from electrical corrosion if the connections between the rails are kept good, but there may be an off-set of 1,000 feet, or 2,000 feet with a poorly laid road.

Mr. Richards. I will say that sometimes, if a service pipe is laid in a street which has been filled in with coal ashes, the ashes will "beat electricity out of sight" in eating up the pipe. That happens once in awhile.

Mr. Naylor. About four years ago I laid some tarred pipe in a wet place, and about two months ago I had a burst in it and took it up. I found the pipe entirely eaten away. In some places for a couple of feet it seemed to be all eaten from the outside. In another locality I ran across a piece of pipe of this same kind, which was laid 18 years before, and it was just as fresh as if it was newly laid. This was upon a hill, where everything was dry. So it seems to me that a good deal depends upon the ground that the pipes are laid in. It is our experience in Maynard that our pipes rust from the outside quicker than from the inside. We do not seem to have any trouble with the inside of cement-lined pipe, but we have a good deal of trouble with the outside.

Mr. Porter. It seems to me it would be interesting to know if anyone else has had experience with defects in the use of tin-lined iron pipe, because, even if this is not the ideal pipe, it seems to promise very well for use in special cases. I know I put it into my own house, in a case where, perhaps, it was unnecessary, as a precaution, as we had had a very unfavorable experience in the family with the use of lead pipe, and we desired to avoid every possibility of danger that we could. If there are weaknesses in the use of this pipe, such as have been spoken of, I think it would be very desirable to have them made known.

The President. If anyone can answer Mr. Porter's question from experience, we would like to hear from him now. Our experience with tin-lined pipe is rather limited. Personally I know nothing about it, for I haven't used any of it, and it is comparatively new. Apparently there is no one here who has had experience with it long enough to state anything about it.

MR. BANCROFT. We have been using lead-lined pipe for three years. We haven't used any tin-lined on services, although I have put some of it into my own house. We have never had any trouble with the lead-lined pipe, such as has been spoken of as occurring with the tin-lined. I don't know why it should not apply to one as well as to the other, and I suppose the process of lining with tin is the same as the process of lining with lead at the present time.

MR. RICHARDS. I will say the pipe I referred to was made, my impression is, some 10 or 15 years ago, by New York parties, who made a specialty of tin-lined iron pipe at that time. Whether it was made in the same manner that tin-lined iron pipe is made at present I do not know, but that was made by expanding a tube of tin inside of the iron pipe. The result of using it was as I have stated, and in quite a number of cases it had to be taken up.

MR. BEALS. Why should not the same experience be had with tin-lined iron pipe as with block tin, regardless of the iron? I have had some experience, not in connection with our water works system, but with one or two wells in town, before we had our system of water supply, where the parties thought they would get the best thing they could and selected block tin. In two years the pipe was so honeycombed they could not pump water through it; they pumped air. I wonder if they would not be liable, with the same water, to get the same result in the use of tin-lined iron pipe—that is, that the tin would honeycomb and the water would go through it and rust the iron.

It seems to me there must be some difference in plain iron pipes. I have in mind now a service—our regular service pipes are cement-lined iron—I have in mind a house which was piped, after the service was in the cellar, with plain black iron pipe, and I have had complaints enough from that this year to make a superintendent run mad almost, of the quality of the water in that service. The woman of the house said it was so poor she could not use it; she had tied a cloth over the faucet and had tried to filter it in all ways, but she had to go to her neighbor's to get water she could use. Now, the neighbor's house was piped with the same class of pipe, plain iron. Well, the owner of the building finally took out the old piping entirely and put in new iron pipe, and the lady of the house comes around and says the water is tip-top. Now, it seems to me

there must be some difference in iron pipe, because there are two houses within 200 feet, both piped with plain iron, and in one case the water was so bad that the people had to go to the other house to get their water, and when the old pipe was taken out and new put in there was no further trouble.

Mr. Hawley. When this matter of a change in the material for services came up last spring, in conversation with some of the plumbers I was told by one of them that he had used some tin-lined pipe 10 or 12 years ago, and at my request he took out several pieces of the pipe and showed it to me. I don't know the process by which that was manufactured, I don't know who manufactured it, or where it came from, but the tin was in perfect condition, while the iron was somewhat corroded from the outside where it had been in the ground. I based my recommendation of tin-lined pipe on that. Now, as to the difference in iron pipes. There is unquestionably a difference in quality. I know of services today in Atlantic City that have been in 10 or 12 years which are still very satisfactory; and I know of other services of the same size, which have been in less than half the time, which have completely filled, or practically so. I have seen a $\frac{3}{4}$-inch galvanized pipe which has been in four years and a half so filled up it had less than the capacity of a $\frac{1}{4}$-inch pipe, and I have seen other services of the same kind, which have been in longer than that, where the pipe is still comparatively free.

Mr. Bancroft. As the question of electrolysis has been brought up here, I would like to inquire if anybody can tell how small a voltage on a pipe line will do damage to pipe, either to a main or services?

The President. I would answer the gentleman's question by saying that a little was bad and a good deal was worse. We have heard considerable about lead-lined pipe being injurious to health, or I take it that that is what has been meant. Now, Mr. Richards has lived in a city, and has had charge of the water works there, and in his long experience there has been no trouble from the use of lead-lined pipe. There are other gentlemen here who have felt serious ill effects from its use right in their own families. This would seem to show conclusively that lead-lined pipe may be affected by some waters and not affected by others. I used to feel a good deal of fear about the use of lead-lined service pipe, but I have been

getting over that fear lately, from the fact that the authenticated cases of poisoning from its use have received so little prominence. If there is anybody here who has a well authenticated case of poisoning from water through a lead-lined pipe, I should like to hear a little something in that direction.

MR. NAYLOR. When a gentleman of our town built his house he had a driven well and put in a very heavy lead pipe. The members of his family have been sick more or less ever since, and there have been a number of deaths. At one time, after our water works were put in (his house was a considerable distance from our main pipe), he ordered his machinist to come up and see what was the trouble with his pump. They kept fixing the pump and fixing it, and finally they came to the conclusion the trouble was not above but below, for whatever they did they couldn't make the pump work. So they got down into the well, and when they got there so as to get hold of the pipe, it crushed right up. The water had eaten the lead pipe entirely away so there was nothing left but a shell which was all full of holes. He was satisfied that the water had eaten the lead and they had drunk it. So he sent for me and wanted to know how soon I could get our water into his house, for he didn't want to drink another drop out of the well. We put the water in, and I believe they have had better health as a family since they stopped using well water through that lead pipe.

THE SECRETARY. What sort of a pipe are they drawing their water through now?

MR. NAYLOR. They are drawing the water through a 4-inch iron pipe, cement-lined, into the cellar, and tarred iron pipe up to the sink.

MR. RICHARDS. I agree with you, Mr. President, that I should like to know of a well authenticated case of lead poisoning from the use of a lead service pipe. I know of cases of poisoning from a pipe running from a well, from a spring and from a lead-lined tank, and other similar cases, but I never heard of a case in connection with a service pipe running from a water main into a house, and I have never seen a description of such a case anywhere in this country, although I have looked for them continually. And I doubt very much if there ever has been a case of lead poisoning from a service pipe extending from a water main into a house and constantly filled with water, unless the water was of exceptional quality.

We are talking about service pipe now, and not talking about pipe from wells or pipe from springs, which is a different thing entirely.

Mr. Hazen. I would refer the gentleman to the reports of the English local government boards for a good many hundreds of cases. In some of the English cities, notably Sheffield, where the water is a surface water from reservoirs, distributed through iron mains and lead service pipes, the water occasionally becomes acid and takes up the lead from the service pipes in quite large quantities; and there have been, not single cases, but hundreds and thousands of cases of lead poisoning at those times. The remedy which has finally been adopted is to treat the water in a certain way to remove the acid and make it alkaline, and when that is done the trouble from the solution of the lead disappears.

A Member. This question has been brought up in a manner which would tend to make us ask for more correct information than we have had on this subject. We have used in our works lead pipes for over 50 years, and have had no trouble whatever from any defect on the inside of the pipe. They have been eaten on the outside, where they have been laid in coal ashes, or certain kinds of clay. I think it would be a matter of useful information to the members of this Association if gentlemen who have used lead pipes on their works would communicate their experience to the Secretary, for if there are any injurious results from the use of lead pipe, we ought to know it and in an authentic manner.

Mr. Bancroft. In my remarks before I stated we were using lead-lined pipe for service pipe, and that I had used a tin-lined pipe in my own house. I did not use tin-lined pipe from any fear of the lead-lined pipe, but for the purpose of experimenting with the tin-lined.

Mr. Porter. I have used tin-lined pipe somewhat for the same reason that the gentleman has just stated, but partly also as a precaution. The unfortunate experience to which I alluded a while ago was this—that a member of our family died a few years ago from illness which was declared by an able physician to be unquestionably the result of lead poisoning, and several other members of the family appeared to have been affected by it also. This was shown by analyses by Prof. Wood, of the Harvard Medical School. Now, the source of that poisoning was never known with certainty, but it was supposed in the case of the person who died to have been

in water from a spring in the country, which was carried through about 700 feet of small lead pipe to the house ; but it was running continuously, never stopped. In the case of city service pipes I suppose, from all I have heard and read, that there is ordinarily very little danger, but I suppose there may possibly be some danger from the use of the water by a servant in the morning from pipes in which it has been standing all night long. Practically that is a very slight danger, but I think it is one perhaps worth considering.

PROCEEDINGS OF THE SIXTEENTH ANNUAL CONVENTION.

Newport, R. I., September 8, 9, 10, 1897.

The headquarters of the Association during the convention were at the Ocean House, and the sessions of the convention were held in the large parlor of the hotel.

Wednesday, September 8, 1897.

The convention was called to order at 11.50 a. m. by President Haskell.

On motion of Mr. Holden the reading of the minutes of the last meeting was dispensed with.

The President introduced His Honor Patrick J. Boyle, Mayor of Newport, who spoke as follows:

ADDRESS OF WELCOME BY MAYOR BOYLE.

Mr. President and Members of the New England Water Works Association, Ladies and Gentlemen:

It affords me much pleasure to meet you today and bid you welcome to our city. We assure you that we are much gratified to have with us the representatives of that business or profession that has done so much in the past, and will, we hope, do so much more in the future for the common good. I assure you that we are very much pleased to have you here, but the welcome which I extend to you must at the best seem, I am afraid, rather a cool one. We unfortunately (with all due respect to the wisdom of the early founders of this city of ours) live under a charter which prohibits the city government from appropriating money for the purposes of entertaining such bodies as yours. I simply call your attention to this fact in order that you will understand that we do not lack appreciation of your coming, and regret that as a city we are unable to take fitting recognition of your presence.

Coming as you do from different parts of New England, you must be acquainted with the many attractions in Newport, and I there-

fore will not detain you from your business by any reference to them. I hope that your deliberations will result in the improvement of the sanitary condition of your respective communities, and I sincerely trust (and I think I have my fellow citizens with me when I say it) that your deliberations will result in some improvement in our local water matters here.

Ladies and gentlemen, I hope you will have a pleasant time while you are with us, and that when you leave us you will take home with you many pleasant recollections of your visit. (Applause.)

RESPONSE BY PRESIDENT HASKELL.

Mr. Mayor:

In behalf of the New England Water Works Association I desire to thank you for your friendly interest in our welfare, and to extend to you and to the citizens of Newport a cordial invitation to attend our meetings.

It has long been the desire of the members of this Association to visit this beautiful city, situated on the picturesque shores of Narragansett bay, and abounding as it does in so many natural and historical objects of interest, enhanced by the lavish display of art, made possible by the possession of great wealth. Although it has always been the object of these meetings to add to our fund of useful knowledge in all that appertains to the proper conduct of a water supply, it has been our custom in the past to devote a portion of our time to recreation, assembling, as we have done, in different cities from year to year, and visiting the principal objects of interest to be found in the immediate vicinity. While our stay with you will be short, I do not doubt that our members will avail themselves of every opportunity to its utmost.

The convention then proceeded to the regular order of business.

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, with the approval and recommendation of the Executive Committee:

RESIDENT ACTIVE.

Frank S. Bailey, Assistant in City Engineer's Office, Brockton, Mass.; John D. Adams, Water Commissioner and Superintendent, Provincetown, Mass.; Thomas H. Rogers, Pumping Engineer for the Pennichuck Water Works, Nashua, N. H.

NON-RESIDENT ACTIVE.

Harry A. Lord, Superintendent, City Water Works, Ogdensburg, N. Y.; W. C. Hawley, Superintendent Water Department, Atlantic City, N. J.; Robert S. Weston, First Assistant Chemist, Louisville Experiment Station, Louisville Water Co., Ky.

ASSOCIATE.

Lead Lined Iron Pipe Co., Wakefield, Mass.; W. K. Helmer, Agent Holly Manufacturing Co., Lockport, N. Y.; Kennedy Valve Co., 75 John St., New York.

On motion of Mr. Fuller, the Secretary was empowered and directed to cast the vote of the Association in favor of the applicants, which he did, and they were declared by the President elected to membership.

The President then delivered his annual address.

ADDRESS OF PRESIDENT HASKELL.

Gentlemen of the New England Water Works Association :

We are now assembled to hold the sixteenth annual convention of this society. The usual time for our annual meeting is in June. The reasons that led to the adoption of this later date were the better facilities afforded for our accommodation here, and that many of our members can better afford to take this time to be absent from their routine of duties.

Since our last meeting, death has removed from our membership:

Albert F. Noyes, Civil Engineer, Boston, Mass.; Richard R. Yates, Superintendent, Northboro, Mass.; Jos. A. Lakewood, Superintendent, Yonkers, N. Y.; Charles B. Brush, Engineer and Superintendent, Hackensack Water Co., Hoboken, N. Y.; Jas. Hugh Stanwood, Prof. Civil Engineering, Institute Technology, Boston, Mass.; Ezra Clark, President and Superintendent, Hartford, Conn.; Wm. E. Nason, Superintendent, Franklin, Mass.; Wilmer Reed.

Among their number the most familiar countenance was that of Mr. Noyes, a former president of this Society, and also an ex-president of the Boston Society of Civil Engineers. His genial presence and hearty interest in our welfare displayed at all of our meetings will be sadly missed.

Our membership is still increasing; we now have 464 Active, 80 Associate, and 5 Honorary members, a total of 549. We must, however, bear in mind that numbers alone do not constitute the greatest strength, but that the best results can only be secured by

earnest work on the part of those who, having valuable knowledge, are willing to contribute it for the benefit of others.

The principal good to be derived from this Association is to be gathered from the papers contributed and the opportunity afforded for the discussion of any points not fully understood.

Our regular meetings have been well attended and a lively interest was shown in the various papers presented.

On September 9th, 1896, the Society visited the Hobbs Brook Reservoir, a new addition to the Cambridge Water Supply, containing 2,000,000,000 gallons storage capacity. Under the guidance of Mr. L. M. Hastings, the City Engineer of Cambridge, an opportunity was given to inspect the method of construction employed in building the lower dam, and the extensive removal of soil and muck from the bed of the reservoir, which was being excavated five feet, whenever that depth of soil was found, necessitating the removal of 1,900,000 cubic yards of material.

On June 9th, 1897, a visit was made to the Metropolitan Water Works at Clinton, where a reservoir is to be built for the Metropolitan district of 63,000,000,000 gallons storage capacity.

Under the guidance of Chief Engineer Stearns and Deputy Engineers Richardson and Miller, the party proceeded over the site of the reservoir through a portion of the tunnel and along the line of conduit to the bridge upon which the conduit crosses the Assabet river.

These excursions to works of such magnitude, presented many instructive features. A severe rainstorm interfered somewhat with the pleasure of each day.

During the most intense heat of the summer our permanent headquarters in the Tremont Temple supplied us with a cool and comfortable place in which the current magazines of the day and a library containing an extensive fund of information on the subject of Water Works could be examined. Our short experience in its occupancy has fully demonstrated its value.

As we look over the problems presented in procuring a water supply for a large city, the question of the purity of the water furnishes a subject of vital interest to all. All will admit that pure water is necessary for the preservation of health. Many instances can be cited in recent years where efforts to improve the quality of water supplied has reduced the death rate of a community in a marked degree.

The remarkable discoveries made by medical science of recent date have shown more fully than was possible in the past, the intimate relation that water bears to perfect health.

These undeniable facts present to us most forcibly the question of water purification. The experience of the past shows us most conclusively that natural ponds cannot be depended upon at all times to furnish pure and wholesome water, and that artificial reservoirs are still more unreliable. The solution of this problem will undoubtedly be reached at a no distant date, through Legislative enactments making the thorough filtration of all surface water supplies compulsory.

It is with feelings of deep regret that I announce the resignation of Mr. Allen Hazen, the senior editor of the JOURNAL, who will not be able in the future to fulfil the duties of that office.

In conclusion I desire to thank all who have assisted me in the effort to make our meetings interesting and instructive.

The Treasurer then submitted his annual report as follows :

REPORT OF THE TREASURER.

George E. Batchelder, in Account With the New England Water Works Association.

RECEIPTS.

1896.	Balance on hand as per last report :		
	People's Savings Bank.	$1,052.64	
	City National Bank	416.74	
	Safe Deposit and Trust Co.	1,235.07	
			$2,704.45
July 21.	Received from J. C. Whitney, Secretary	$ 700.00	
Dec. 30.	" " " "	400.00	
1897.			
Jan. 8.	" " " "	200.00	
" 19.	" " " "	300.00	
" 29.	" " " "	250.00	
Mch. 1.	" " " "	300.00	
May 11.	" " " "	300.00	
June 1.	" " " "	300.00	
" 3.	" " " "	300.00	
" 8.	" " " "	150.00	
			$ 3,200.00
Aug. 1.	People's Savings Bank, interest	$ 63.76	
Sept. 1.	Safe Deposit and Trust Co., interest	69.47	
" 1.	City National Bank, interest	7.00	
			$ 140.23
			$6,044.68

EXPENDITURES.

1896.			
June	12.	James T. Almy, badges	$ 8.96
"	12.	Frank De Silva, lettering door of headquarters	1.86
"	12.	Newton Journal, printing circulars and postals	16.50
"	12.	A. T. Thompson & Co., lantern service, Lynn	22.70
"	15.	Alfred Mudge & Son, printing postals, etc	8.00
"	16.	Irving & Casson, upholstering two chairs	40.00
"	24.	Bacon & Burpee, reporting Lynn meeting	75.00
"	30.	Fanning Printing Co., printing envelopes	3.00
July	1.	Thos. Campbell, 2d, table for Lynn meeting	5.02
"	1.	Electro-Light Engraving Co., electro for adv	1.08
"	14.	Newton Journal, printing envelopes, circulars and postals	9.00
Aug.	2.	The Oxford Club, Lynn, hall for June meeting	55.00
Sept.	1.	J. C. Whitney, stamps, stationery, express, telegrams, telephone, etc	99.31
"	1.	J. C. Whitney, salary to Sept. 1, 1896	125.00
"	4.	Miss A. B. Knowlton, typewriting	14.00
"	18.	The Heliotype Printing Co., plates and half tone plates	51.18
Oct.	1.	Stephen F. Cate Estate, barges for Sept. meeting	22.00
"	10.	The Heliotype Printing Co., two half tone plates	6.00
"	12.	W. H. Richards, salary to Sept. 1, postage, freight, express, etc	86.03
"	15.	Boston Society of Civil Engineers, rent of rooms to Sept. 1, 1896	150.00
Nov.	2.	Mrs. A. D. Wood, basket of roses	10.00
"	24.	Alfred Mudge & Son, printing June Journal	294.80
Dec.	8.	Electro-Light Engraving Co., five half tones engineering constructions	28.31
"	11.	The Heliotype Printing Co., one zinc plate	1.68
"	12.	J. C. Whitney, express, freight, telegrams, telephone, etc	15.40
"	12.	J. C. Whitney, salary to Dec. 1, 1896	125.00
1896.			
Dec.	14.	W. H. Richards, salary, telegrams, telephone, express, typewriting, etc.	99.69
"	14.	The Heliotype Printing Co., 850 copies each two diagrams and one map	39.00
"	31.	Alfred Mudge & Son, printing September Journal	183.00
1897.			
Jan.	1.	Boston Society of Civil Engineers, rent of rooms to Jan. 1, 1897	100.00
"	25.	Newton Journal, printing circulars, etc	9.00
Feb.	24.	The Heliotype Printing Co., 870 copies plan of New Bedford Water Works	17.50
		Amount carried forward	$1,723.02

		Amount brought forward	$1,723.02	
Feb.	26.	The Heliotype Printing Co., five half tone plates.	27.60	
Mch.	8.	Newton Journal, printing circulars and envelopes	21.50	
"	11.	Bacon & Burpee, report of winter meeting	75.75	
"	15.	The Heliotype Printing Co., one half tone plate	5.52	
"	26.	W. H. Richards, postage, express, telegrams, typewriting and salary to March 1	99.96	
"	27.	J. C. Whitney, back numbers of Journal, express, telegrams, typewriting, etc.	116.60	
"	27.	J. C. Whitney, salary to March 1, 1897	125.00	
"	31.	Fanning Printing Co., 850 half tones of A. F. Noyes	5.00	
Apr.	7.	Alfred Mudge & Son, printing December Journal.	191.75	
"	8.	The Heliotype Printing Co., one half tone plate	5.52	
"	10.	The Heliotype Printing Co., one zinc plate map	2.60	
"	14.	The Heliotype Printing Co., one half tone pencil drawing	5.06	
"	21.	The Heliotype Printing Co., three half tone plates	16.56	
May	21.	Allen Hazen, services of assistant, express and telegrams	34.50	
"	24.	Electro-Light Engraving Co., one eng. diagram	1.04	
"	27.	The Heliotype Printing Co., 3,050 copies plans water filter at Ashland, Wis	28.50	
June	1.	Boston Society of Civil Engineers, rent to June 1, 1897	150.00	
"	7.	W. H. Richards, salary to June 1, 1897, postage, express, etc.	84.56	
"	7.	J. C. Whitney, postage, express, typewriting, travel, etc.	19.97	
"	7.	J. C. Whitney, salary to June 1, 1897	125.00	
July	3.	Alfred Mudge & Son, printing March Journal	384.83	
"	3.	W. H. Richards, postage, express, telegrams, telephone, etc.	35.85	
Aug.	28.	Alfred Mudge & Son, 900 copies and 800 slips of three cuts and rebinding 100 pamphlets	8.25	
"	28.	Newton Journal, printing postals, receipts and circulars	7.25	
"	28.	J. C. Whitney, back numbers of Journal	21.75	
				$3,322.94

Balance on Hand.

Aug.	1.	People's Savings Bank	$1,116.40	
Sept.	1.	Safe Deposit & Trust Co	1,377.48	
"	1.	City National Bank	227 86	
				$2,721.74
				$6,044.68

Respectfully submitted,

George E. Batchelder, *Treasurer.*

Examined, audited and found correct.

A. R. Hathaway, } *Finance Committee.*
A. W. F. Brown, }

September 4, 1897.

On motion of Mr. Beals, the report of the Treasurer was accepted and placed on file.

On motion of Mr. Holden, the report of the Auditing Committee was accepted and placed on file.

The Secretary submitted the following as his report:

REPORT OF THE SECRETARY.

Summary of Statistics Relative to Membership for Year Ending June 1,'97.

ACTIVE MEMBERS.

June 1, 1896, total active membership		442	
Withdrawals during the year		11	
		431	
INITIATIONS:			
June, 1896	15		
December, 1896	6		
January, 1897	2		
February, 1897	5		
March, 1897	5		
		33	
June 1, 1897, total active membership			464

HONORARY MEMBERS.

June 1, 1896, total honorary membership		5	
June 1, 1897, total honorary membership		—	5

ASSOCIATE MEMBERS.

June 1, 1896, total associate membership		82	
Withdrawals during the year		6	
		76	
INITIATIONS:			
June, 1896	1		
December, 1896	2		
January, 1897	1		
		4	
June 1, 1897, total associate membership			80
June 1, 1897, total membership			549

A gain for the year of 20.

Summary of Receipts for the Year Ending June 1, 1897.

DR.

Received for advertisements	$ 1,355.00
" initiation	166.00
" annual dues	1,508.00
" Journals	149.00
" miscellaneous	22.00
	$3,200.00

Cr.

1896.			
July 20.	Paid Geo. E. Batchelder, Treasurer	.... $	700.00
Dec. 30.	" "	....	400.00
1897.			
Jan. 8.	" "	....	200.00
Jan. 18.	" "	....	250.00
Jan. 27.	" "	....	300.00
Mch. 8.	" "	....	300.00
May 10.	" "	....	300.00
May 29.	" "	....	300.00
June 2.	" "	....	300.00
June 7.	" "	....	150.00
			$3,200.00

On motion of Mr. Beals, it was voted that the report be accepted and placed on file.

AFTERNOON SESSION.

Edward V. French of Boston opened the afternoon session by reading a paper entitled "Loss of Pressure Caused by Meters on a Factory Fire Supply." The paper was discussed by the President, Mr. Fish, Mr. Walker and Mr. Fuller, and in answer to suggestions by them, Mr. French explained more fully certain matters considered in his paper.

The next paper was by Frank L. Fuller of Boston, and related to "Sinking Funds." The President and Messrs. Smith, Gilbert, Beals and Hawley took part in the discussion which followed.

Henry A. Cook, Supt., Salem, Mass., was announced upon the program to speak upon "The Water Supply of Salem." Mr. Cook announced that he had not had opportunity to prepare a paper, but at the request of certain members of the Association he exhibited two tools which he had found convenient to use in his work. One was a very ingenious electric lighting arrangement, which can be easily carried by the workman, used for examining the interior of a service box. The other was an appliance for removing an obstruction, like a small stone, from a service box.

EVENING SESSION.

At the evening session George C. Whipple, Biologist and Director of the Mt. Prospect Laboratory, Brooklyn Water Department, Brooklyn, N. Y., read a paper entitled "Some Observations on the Growth of Organisms in Water Pipes." Messrs. Fuller, Chace and the President took part in the discussion.

George F. Chace, Supt., Taunton, Mass., read a paper on "Service Pipe Defects and the Remedy." There was a long discussion upon this paper, participated in by Messrs. Fish, Bancroft, Hawley, Gilbert, Richards, Naylor, Porter, Beals and Hazen.

Mr. Hazen presented to the convention Mr. Nicholas Simin, Chief Engineer of the water works of Moscow, Russia, who, he said, had come a very long distance to attend the meeting of the Association, and he trusted the members would give him a cordial welcome. Mr. Simin was received with loud applause. He responded in his native language. [The following translation of what he said was kindly furnished by his daughter, who, with a lady friend from Moscow, is accompanying Mr. Simin upon his tour in this country :]

Ladies and Gentlemen: I am very glad to be among you in your beautiful country. America is a country where people know how to approach each question bravely, and rapidly to come to its solution, conquering all the hindrances met on the way. In America it is not only spoken of things, but it is done, and done quickly, without delay.

The progress of the technique is here astonishing. The water works art, for the study of which I came here, has received in your country an immense development, which answers perfectly well to all the requests put by science and by life.

Gentlemen, I thank you heartily for your amiable attention, and I welcome you as intelligent representatives of the water works art of your great country. (Loud applause.)

THURSDAY, September 9th.

At the morning session Mr. Byron I. Cook, Superintendent, Woonsocket, R. I., read a paper entitled "Reservoir and Dam No. 3, Woonsocket Water Works." The paper was discussed by Messrs. Stacey, Chace and Hazen, and the President.

Mr. George A. Stacey, Superintendent, Marlboro, Mass., spoke on "Service Boxes," and was followed by Messrs. Gilbert, Fish and Fuller.

Mr. Henry F. Jenks of Pawtucket, R. I., who had charge of the exhibit of associate members, presented his report.

Mr. W. C. Hawley, Superintendent, Atlantic City, N. J., then addressed the convention, giving the results obtained by the use of water meters at Atlantic City.

In the evening Mr. Frederick P. Stearns, Chief Engineer of Metropolitan Water Board, gave an illustrated talk on the "Metropolitan Water Supply of Massachusetts."

He was followed by Mr. H. F. J. Porter with a talk on "Steel Forgings," illustrated by stereopticon views of the machinery and interior of the shops of the Bethlehem Works, and the processes of manufacture.

Friday, September 10th, 1897.

The first business was the election of new members. The Secretary read the following names of applicants, duly approved and recommended by the Executive Committee:

Resident Active.

Arthur F. Estabrook, Water Commissioner, Leicester, Mass.
E. V. French, Civil Engineer, Boston, Mass.
J. B. Putnam, Superintendent, Westboro, Mass.
Franklin H. Robbins, Civil Engineer, Boston, Mass.
J. A. St. Louis, Water Registrar, Marlboro, Mass.
Chas. W. Sherman, Civil Engineer, Boston, Mass.

Non-Resident Active.

Geo. B. Bassett, Civil Engineer, Buffalo, N. Y.
A. D. Clark, Secretary Water Company, Kane, Penn.
Wm. H. Dean, Analyst, Wilkesbarre Penn.
A. S. Gear, Superintendent, Supply Yards, New York City, N. Y.
Harvey M. Geer, Civil Engineer, Ballston Spa, N. Y.
James H. Harlow, President Pennsylvania Water Company, Wilkinsburg, Penn.
Hibbert Hill, Biologist Laboratory Brooklyn Department of Health, Rockville Centre, Long Island, N. Y.
Emil Kuichling, Chief Engineer, Water Works, Rochester, N. Y.

Associate.

Buffalo Meter Company, Water Meters, Buffalo, N. Y.
B. F. Smith & Bros., Driven Wells, Boston, Mass.

On motion of Mr. Fuller, the Secretary cast the ballot of the Association in favor of the applicants, and they were declared elected.

ELECTION OF OFFICERS.

Mr. Coggeshall, for the Nominating Committee, reported the following list of officers for the ensuing year:

PRESIDENT.

WILLARD KENT, Manager Water Company, Narragansett Pier, R. I.

VICE-PRESIDENTS.

MELVILLE A. SINCLAIR, Superintendent, Bangor, Me.; CHARLES K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent, Burlington, Vt.; JOSEPH G. TENNEY, Superintendent, Leominster, Mass.; BYRON I. COOK, Superintendent, Woonsocket, R. I.; THEODORE H. MCKENZIE, Manager, Southington, Conn.

SECRETARY.

JOHN C. WHITNEY, Water Registrar, Newton, Mass.

TREASURER.

GEORGE E. BATCHELDER, Water Registrar, Worcester, Mass.

SENIOR EDITOR.

JOSEPH E. BEALS, Superintendent, Middleboro, Mass.

JUNIOR EDITOR.

WALTER H. RICHARDS, Superintendent, New London, Conn.

EXECUTIVE COMMITTEE.

LOUIS M. BANCROFT, Superintendent, Reading, Mass.
JOHN C. HASKELL, Superintendent, Lynn, Mass.
A. H. SALISBURY, Superintendent, Lawrence, Mass.

FINANCE COMMITTEE.

A. R. HATHAWAY, Water Registrar, Springfield, Mass.
A. W. F. BROWN, Water Registrar, Fitchburg, Mass.
WILLIAM MCNALLY, Marlboro, Mass.

Mr. Holden moved that the report of the committee be accepted, and that the Secretary be directed to cast the ballot of the Association for the nominees.

At the request of Mr. Cavanagh the motion was divided, and the convention voted to accept the report of the committee.

Mr. Cavanagh then moved that the name of Mr. Robert J. Thomas, of Lowell, be added to the nominations for the Executive Committee. Mr. Salisbury thereupon withdrew his name, which had been presented by the nominating committee, and the convention voted to substitute the name of Mr. Thomas. Then, on motion of Mr. Cavanagh, the Secretary was directed to cast the ballot of the Association for the nominees, and they were declared elected.

President Haskell, on leaving the chair, spoke as follows:

Gentlemen of the New England Water Works:

I take pleasure in presenting to you Mr. Willard Kent, whom you have elected to preside over the affairs of this Association for the ensuing year. I trust you will all give to him throughout the year your most hearty support. (Applause.)

President Kent responded as follows:

Gentlemen:

I thank you. I assure you I fully appreciate the honor of the presidency of the New England Water Works Association, and I regret that I have not the command of words fittingly to express that appreciation. With your assistance I will endeavor to maintain the present high standing of the Association, so far as it is within my power.

On motion of Mr. Holden the convention adjourned.

Attendance at Convention held September 8, 9 and 10, 1897.

ACTIVE MEMBERS.

Abbott, E. L., Boston, Mass.
Bates, Oren B., Clinton, Mass.
Bancroft, Lewis M., Reading, Mass.
Bisbee, F. E., Auburn, Me.
Batchelder, G. E., Worcester, Mass.
Beals, Jos. E., Middleboro, Mass.
Brooks, E. C., Cambridge, Mass.
Baldwin, Chas. H., Boston, Mass.
Bigelow, James F., Marlboro, Mass.
Bowers, George, Lowell, Mass.
Brackett, Dexter, Boston, Mass.
Bartlett, R. S., Norwich, Conn.
Coggeshall, R. C. P. New Bedford, Mass.
Chace, George F., Taunton, Mass.
Cook, Henry A., Salem, Mass.
Chadbourne, E. J., Wakefield, Mass.
Cook, Byron I., Woonsocket, R. I.
Codd, W. F., Nantucket, Mass.
Cavanagh, John F., Quincy, Mass.
Crowell, Geo. E., Brattleboro, Vt.
Crandall, Geo. K., New London, Conn.
Crawford, J. W., Lowell, Mass.
Chandler, C. E., Norwich, Conn.
Doane, A. O., Newton, Mass.
Daboll, L. E., New London, Conn.
Estabrook, A. F., Leicester, Mass.
Fish, J. B., Scranton, Pa.
Fuller, F. L., Boston, Mass.
French, E. V., Boston, Mass.
Gould, Amos A., Leicester, Mass.
Glover, Albert S., Boston, Mass.
Gilbert, J. C., Whitman, Mass.
Gleason, T. C., Ware, Mass.
Gear, A. S., New York, N. Y.
Huntington, Jas. A., Haverhill, Mass.
Hawley, W. C., Atlantic City, N. J.
Haskell, John C., Lynn, Mass.
Holden, H. G., Nashua, N. H.
Hayes, A. G., Middleboro, Mass.
Hastings, V. C., Concord, N. H.
Hazen, Allen, New York, N. Y.
Hyde, H. N., Newton, Mass.
Harrington, G. W., Wakefield, Mass.
Hammatt, E. A. W., Boston, Mass.
Hill, W. R., Syracuse, N. Y.
Kent, Willard, Narragansett Pier, R. I.
Kuichling, E., Rochester, N. Y.
Kempton, D. B., New Bedford, Mass.
Kingman, Horace, Brockton, Mass.
Kieran, Patrick, Fall River, Mass.
Luther, Wm. J., Attleboro, Mass.

Locke, James W., Brockton, Mass.
Morse, J. W., Natick, Mass.
McKenzie, T. H., Hartford, Conn.
Northrop, F. L., Milford, Mass.
Nichols, Edw. C., Reading, Mass.
Naylor, Thomas, Maynard, Mass.
Perry, F. G., Pawtucket, R. I.
Pollard, W. D., Pottsville, Pa.
Putnam, J. B., Westboro, Mass.
Porter, Dwight, Boston, Mass.
Rogers, H. W., Haverhill, Mass.
Richards, W. H., New London, Conn.
Robertson, W. W., Fall River, Mass.
Sullivan, J. C., Holyoke, Mass.
Smith, H. O., Leicester, Mass.
Sinclair, M. A., Bangor, Me.
Stacy, George A., Marlboro, Mass.
Salisbury, A. H., Lawrence, Mass.
Snow, Edwin W., Somerville, Mass.
Stearns, F. P., Boston, Mass.
Smith, John E., Andover, Mass.
Taylor, L. A., Boston, Mass.
Thomson, John, New York, N. Y.
Tower, D. N., Cohasset, Mass.
Tenney, J. G., Leominster, Mass.
Thomas, R. J., Lowell, Mass.
Whitney, J. C., Newton, Mass.
Welch, J. Alfred, Methuen, Mass.
Winslow, George E., Waltham, Mass.
Wiswall, E. T., West Newton, Mass.
Wallace, E. L., Franklin Falls, N. H.
Walker, Chas. K., Manchester, N. H.
Whipple, G. C., Brooklyn, N. Y.
Watters, Joseph, Fall River, Mass.
Whittemore, W. F., Leicester, Mass.
Zick, W. G., New York, N. Y.

HONORARY MEMBERS.

"Engineering News," of New York, by M. N. Baker.

"Engineering Record," of New York, by H. C. Meyers, Jr., and C. J. Underwood, Jr.

"Fire and Water," of New York, by F. W. Sheppard.

ASSOCIATE MEMBERS.

Ashton Valve Co., Boston, Mass., by C. W. Houghton.

Artesian Well Co., Providence, R. I., by Ray S. Baker.

Ashcroft Mfg. Co., Boston, Mass., by J. A. Mitsch.

Blossom, Albert A., Salem, Mass.

Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.

Chadwick Lead Works, Boston, Mass, by A. H. Brodrick.

Chapman Valve Co., Indian Orchard, Mass., by E. L. Ross.

Coffin Valve Co., Neponset, Mass., by F. E. Adams.

Crosby Steam Gage and Valve Co., Boston, Mass., by Samuel G. Reed.

Deane Steam Pump Co., Holyoke, Mass., by Wm. Burnham, A. M. Pierce and F. H. Hayes.

Eagle Oil and Supply Co., Boston, Mass., by T. J. Babcock and C. N. Goward.

Hersey Mfg. Co., Boston, Mass., by J. E. Safford and J. A. Tilden.

Jenks, Henry F., Pawtucket, R. I.

Kennedy Valve Mfg. Co., New York, N. Y., by M. J. Gilmore.

Lead Lined Iron Pipe Co., Wakefield, Mass., by Thos. E. Dwyer.

National Meter Co., New York City, by John C. Kelley and J. G. Lufkin.

Neptune Meter Co., New York City, by H. H. Kinsey.

Rensselaer Mfg. Co., Troy, N. Y., by Fred S. Bates.

Ross Valve Co., Troy, N. Y., by William Ross.

Anthony P. Smith, Newark, N. J., by W. H. Van Winkle and A. P. Smith.

Sumner & Goodwin Co., Boston, Mass., by F. D. Sumner.

Benj. C. Smith, New York City, by Fred A. Smith.

Thomson Meter Co., Brooklyn, N. Y., by S. D. Higley, E. T. Ivins and Henry C. Folger.

Union Meter Co., Worcester, Mass., by J. P. K. Otis.

Henry R. Worthington, New York City, by O. P. Boller and J. M. Betton.

Wm. Wolfendale, Fall River, Mass.

R. D. Wood & Co., Philadelphia, Pa., by Jesse Garrett.

George Woodman & Co., Boston, Mass., by F. L. Howland.

GUESTS

Ames, C. N., Brockton, Mass.
Bancroft, L. M. Mrs., Reading, Mass.
Beals, Jos. E. Mrs., Middleboro, Mass.
Batchelder, George E. Mrs., Worcester, Mass.
Bacon, James P., Cambridge, Mass.
Burke, M. F., Marlboro, Mass.
Burke, F., Marlboro, Mass.
Bowers, George Mrs., Lowell, Mass.
Bacon, J. P. Mrs., Cambridge, Mass.
Clancey, J. C. Mrs., Syracuse, N. Y.
Codd, W. F. Mrs., Nantucket, Mass.
Carpenter, L. Z., Attleboro, Mass.
Crandall, George K. Mrs., New London, Conn.
Coggeshall, R. C. P. Mrs., New Bedford, Mass.
Clifford, T. C. Mrs., Providence, R. I.
Dean, G. A., Attleboro, Mass.
Daboll, L. E. Mrs., New London, Conn.
Dowd, M. J., Lowell, Mass.
Doane, A. O. Mrs., Newton, Mass.
Estabrooks, A. F. Mrs., Leicester, Mass.
Fish, J. B. Mrs., Scranton, Pa.
Fels, August, Lowell, Mass.
Fels, Mrs., Lowell, Mass.
Fels, Miss, Lowell, Mass.
Fels, Miss, Lowell, Mass.
Faborousky, Miss W., Moscow, Russia.
Glover, Albert S. Mrs., Newton, Mass.
Gould, Amos Mrs., Leicester, Mass.
Gilbert, A. W., Troy, N. Y.
Holden, H. G. Mrs., Nashua, N. H.
Hayes, Maria E. Mrs., Middleboro, Mass.
Hayes, F. H. Mrs., Boston Mass.
Hill, W. R. Mrs., Syracuse, N. Y.
Hawley, C. T., Cambridge, N. Y.
Jenks, Henry F. Mrs., Pawtucket, R. I.
Jenks, Dorothy Miss, Pawtucket, R.I.
Kent, C. A. Mrs., Narragansett Pier, R. I.
Kelley, John C. Mrs., Brooklyn, N. Y.
Kelley, S. T. Miss, Brooklyn, N. Y.
Kelley, E. S. Miss, Brooklyn, N. Y.
Kempton, David B. Mrs., New Bedford, Mass.
Lawrence, W. F., Derby, Conn.
Naylor, Thomas Mrs., Maynard, Mass.
Proctor, C. S. Mrs., Lowell, Mass.
Proctor, H. S., Lowell, Mass.
Pollard, W. D., Pottsville, Pa.
Porter, H. F. J., Bethlehem, Pa.
Plunkett, E. J., Marlboro, Mass.
Porter, Dwight Mrs., Boston, Mass.
Rogers, H. W. Mrs., Haverhill, Mass.
Ross, E. L. Mrs., Indian Orchard, Mass.
Spofford, J. E. Mrs., Boston, Mass.
Simin, Nicholas, Moscow, Russia.
Simin, Olga Miss, Moscow, Russia.
Stacy, G. A. Mrs., Marlboro, Mass.
Salisbury, H. Mrs., Lawrence, Mass.
Thomson, John Mrs., New York, N. Y.
Tower, D. Mrs., Cohasset, Mass.
Tilden, C. F., Cohasset, Mass.
Tilden, J. A. Mrs., Boston, Mass.
Van Winkle, W. H. Mrs., Newark, N. J.
Warde, Charles S., Staten Island, N. Y.
Welch, J. Alfred Mrs., Methuen, Mass.
Wakefield, F. M. Mrs., Syracuse, N. Y.
Whittemore, W. F. Mrs., Leicester, Mass.
Winslow, A. M. Mrs., Waltham, Mass.
Weaver, Frank L., Lowell, Mass.

LIST OF EXHIBITS AT THE CONVENTION.

In Charge of Mr. Henry F. Jenks, Pawtucket, R. I.

Union Water Meter Co., Worcester, Mass., Water Meters, etc.
Hersey Mfg. Co., Boston, Mass., Water Meters.
Builders' Iron Foundry, Providence, R. I., Venturi Water Meters and castings.
Thomson Meter Co., Brooklyn, N. Y., Water Meters.
Neptune Meter Co., New York City, Water Meters.
Buffalo Meter Co., Buffalo, N. Y., Water Meters.
National Meter Co., New York City, Water Meters.
Coffin Valve Co., Neponset, Mass., Valves, Hydrants, etc.
Ross Valve Co., Troy, N. Y., Pressure Regulating Valves, etc.
Kennedy Valve Mfg. Co., New York City, Valves.
M. J. Drummond, New York City, Testings Plugs and Service Boxes.
B. C. Smith, New York City, Pipe Cutting Machine.
A. P. Smith Mfg. Co., Newark, N. J., Tapping Machine.
Rensselaer Mfg. Co., Troy, N. Y., Valves, etc.
Daniel A. Streeter, Waterbury, Conn., Pipe Plugs.
Eagle Oil and Supply Co., Boston, Mass., Metal Polish.
Henry F. Jenks, Pawtucket, R. I., Drinking Fountain.
Lead-lined Iron Pipe Co., Wakefield, Mass., Lead-lined Pipe.
Crosby Steam Gage and Valve Co., Boston, Steam Gauges and Valves.
H. R. Worthington, New York City, Water Meter and Pumping Eng. Model.
Holly Mfg. Co., Lockport, N. Y., Photographs of Pumping Machinery.
Ashton Valve Co., Boston, Steam Gauges and Valves.
Ashcroft Mfg. Co., New York City, Steam Gauges, etc.
R. D. Wood & Co., Philadelphia, Pa., Drawings of Hydrants, etc.
Deane Steam Pump Co., Holyoke, Mass., Steam Pumps.
Fall River Iron Works, Fall River, Mass., Service Boxes.

OBITUARY.

RICHARD R. YATES.—Died Sept. 10th, 1896, aged 62 years. Joined the Association, June 18th, 1885.

Mr. Yates was Superintendent of the Northboro, Mass. Water Works for many years.

CHAS. B. BRUSH.—Died June 3rd, 1897, aged 49 years. Joined the Association, June 16th, 1886.

Mr. Brush graduated as civil engineer from the New York University in which he was for several years a professor of civil engineering. He afterwards devoted himself to a general engineering practice and made a brilliant record as an engineer, being chief engineer of the Hoboken Land and Improvement Co., the North Hudson County Railway Co., the Hoboken Ferry Co., and the Hackensack Water Co. He was a member of many scientific societies, including the American Society of Civil Engineers and the American Water Works Association.

Mr. Brush contributed a valuable paper to this Association on Aeration and Filtration, published in Vol. II., No. 1, p. 71.

JOSEPH A. LOCKWOOD.—Died August 24th, 1897. Joined the Association, Sept. 14th, 1887.

Mr. Lockwood graduated from Union College as a civil engineer, and had been superintendent of the Yonkers, N. Y. Water Works for 25 years.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XII. December, 1897. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

LOSS OF PRESSURE CAUSED BY METERS IN FACTORY FIRE SUPPLIES.

BY E. V. FRENCH, MECHANICAL ENGINEER, BOSTON, MASS.

[*Read Sept. 8, 1897.*]

OBJECT.

The tests described in this paper were made under the auspices of the Factory Mutual Fire Insurance Companies, with the generous cooperation of the Naumkeag Cotton Mills, and the Salem (Mass.) Water Works, and others named below. Their main object was to determine the loss of pressure caused by meters, especially with reference to their use on fire service pipes, and to determine the safest form of meter for this kind of work. The work was all carried on under the general direction of Mr. John R. Freeman.

In the matter of water meters on large fire pipes the interests of the insurance companies and water departments sometimes seem to conflict.

Commonly when starting anew the pipe systems can be so arranged as to provide a small separate pipe into the mill yard for its regular supply for domestic and manufacturing purposes which can be metered while a separate pipe is run for fire purposes alone, which is so simply arranged and with so small possibility of draft that no meter is needed, and more than nine-tenths of the factories insured

in the Factory Mutuals thus find no necessity for use of meters. But there are places where meters on fire supplies appear to be a necessity. We have, therefore, thought that to lay our data before you, thereby making clear the causes of our objections to meters, might encourage the production of some sort of a metering device capable of thoroughly guarding the interests of Water Departments but free from the impairment of fire protection presented in greater or less degree, by all existing meters.

It may be well for the sake of completeness, to briefly restate the insurance companies objections to meters on fire pipes—these are:

1st. Meters obstruct the flow of water, thus lessening the efficiency of fire streams. Many common types of meter that are excellent for accuracy of metering so obstruct the flow as to reduce the pressure under ordinary fire conditions more than one-half.

2nd. The moving parts of many meters in common use, may become so stuck by a stick or stone coming along in the water, as to absolutely prevent the flow of enough water to be of any service whatever for fire work. Moreover, when meters remain idle for long periods, as is often the case on fire pipes, the ordinary sediment in the water is sometimes sufficient to cause sticking.

3rd. The fish-traps necessarily used with most meters, while lessening the danger of the moving parts of the meter becoming blocked, are, themselves always liable to become clogged by pipe scales, leaves, and other similar stuff in the water. This is especially the case with meters on fire pipes, for the draft of water caused by a fire is likely to be so much larger than the normal draft, that it stirs up much sediment which remains quiet in the pipe with ordinary flows.

We have always advised that meters on fire services for those cases where meters absolutely can *not* be avoided, be placed in a by-pass with a gate in the straightway connection which is to be opened in case of a fire, but sealed shut at all other times. While we believe this to be the proper arrangement and worth its cost, it does not furnish a reliable remedy to the above troubles, for in a number of instances in our own experience, such by-passes have been absolutely forgotten in the excitement of a fire. Several of these cases, moreover, happened in plants where the care given to the fire service was excellent in every respect. Only recently one of our inspectors opened four 1-inch streams in a mill yard when the pres-

sure dropped from 70 to 33 pounds; the superintendent then *remembered* that there was a 4-inch meter on the 6-inch supply pipe. When the by-pass was opened the pressure rose to 51 pounds. Many of you will also recall the several examples of similar experiences given by Mr. Freeman in his remarks on this subject at the Hartford convention.

4th. Large meters with necessary gates and fittings, are very expensive and add a considerable percentage to the cost of a mill fire system. As often the amount of money available for such a system is limited, this results in a cutting down of the useful apparatus purchased and a replacing of it by something which actually lessens the efficiency of that which remains.

METERS TESTED AND TIME AND LOCATION OF TESTS.

In addition to the meters designed especially for fire pipes, and therefore designed to give large flows with small losses, a number of other types of meters were tested in order to get fairly complete data on the principal types of meters used, with the idea of getting comparisons and ascertaining what *not* to use on a fire pipe.

The following meters were tested :—

Meters Designed for Large Flows with Small Loss of Pressures:

METERS ADAPTED FOR FIRE SERVICE

Tested at Salem, July, 1896:

4-inch "Gem" meter, manufactured by National Meter Co.
6- " " " " " " " "
4- " "Torrent" meter, manufactured by Hersey Mfg. Co.
8- " " " " " " " "

Tested at Philadelphia, August, 1897:

6-inch By-pass with 2-inch "Crown" meter in the straight pipe.
4- " " " 1½- " " " " " " "
6- " Pratt & Cady check valve with 2-inch "Crown" meter around the check.

The last three meters were made up from ordinary pipe fittings by the Bureau of Water, Philadelphia.

METERS DESIGNED FOR VERY ACCURATE REGISTRY OF FLOWS, LARGE AND SMALL, BUT NOT FOR SMALL LOSSES OF PRESSURE:

NOT WELL ADAPTED FOR FIRE SERVICE.

Tested at Salem July, 1896:

4-inch "Crown" meter, manufactured by National Meter Co.
4- " "Hersey" " " " Hersey Mfg. Co.
4- " "Lambert" " " " Thomson Meter Co.

Tested at Lowell, September, 1897:

4-inch "Union" meter, manufactured by Union Meter Co.

Tested at Salem, July, 1896.

3-inch "Worthington" meter, manufactured by Henry R. Worthington.

The Worthington meter was obtained from the meter department of the City of Boston, through the kindness of Mr. John R. Murphy, water commissioner, the other meters were freely loaned by the manufacturers.

For the Salem tests, we are indebted to the Naumkeag Steam Cotton Co., for the free use of their yard, piping and general facilities, and to the Salem Water Board, who, through their superintendent, kindly granted us the use of the city water. The Lowell tests were made in the yard of the Lawrence Mfg. Co., where every facility was given us. Water from the reservoir of the Proprietors of the Locks and Canals was generously granted by their agent.

The Philadelphia tests were made through the kindness of Mr. John C. Trautwine, Jr., chief of the bureau of water, Philadelphia, and Mr. A. J. Fuller, assistant engineer, who freely granted us full use of their testing apparatus and also gave us the benefit of their tests and investigations on proportional or by-pass meters.

In carrying on these tests the larger part of the observations and computations were made by Messrs. F. M. Herrmann, A. L. Kendall and H. O. Lacount of the Inspection Department of the Factory Mutuals.

METHODS OF TESTING.

Plates I and II show the general arrangements of meters, gages, etc., for testing.

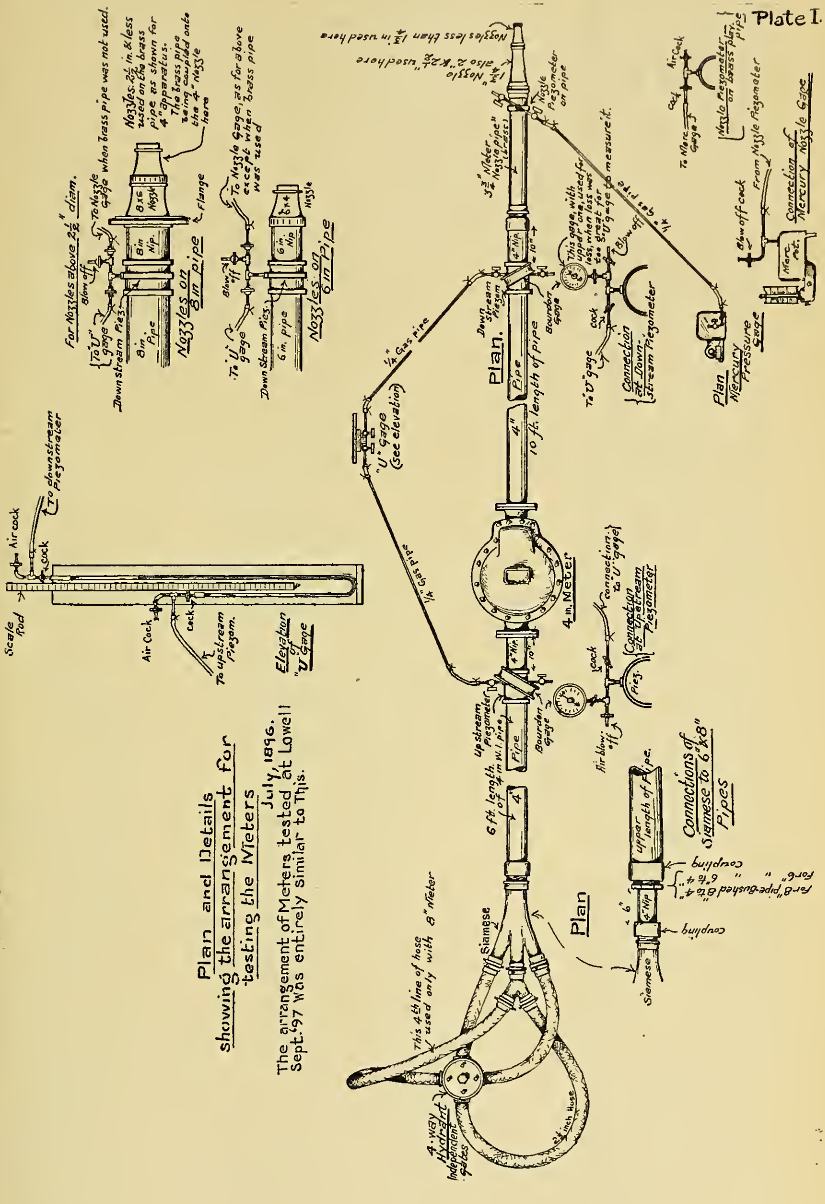
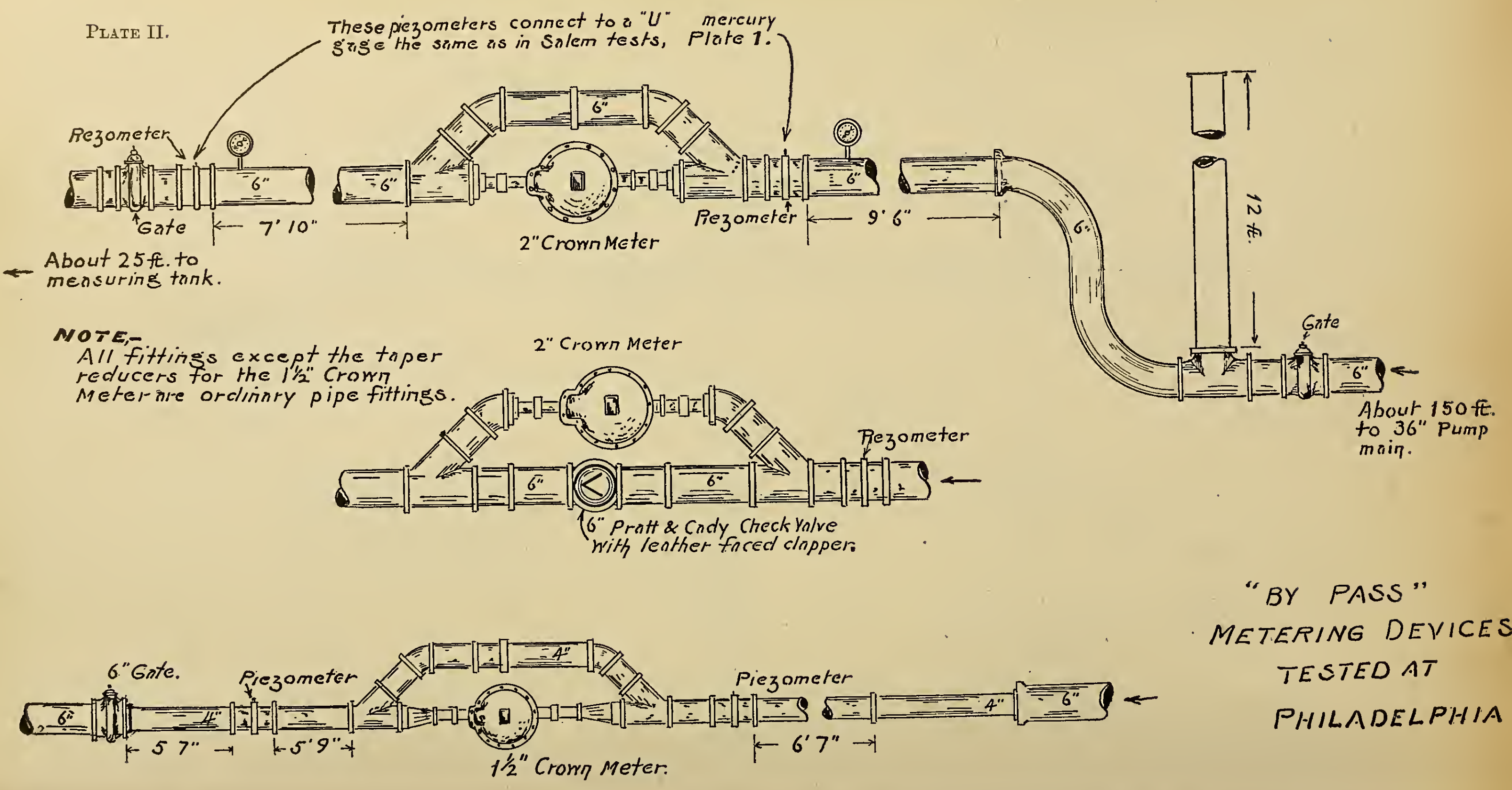


Plate I.
Plan and Details
showing the arrangement for testing the Meters
July, 1896.
The arrangement of Meters tested at Lowell Sept. '97 was entirely similar to This.
Elevation of "U" Gage
Scale Rod
Air cock
cock
To downstream Piezometer
To upstream Piezom.
For Nozzles above $2\frac{1}{2}$" diam.
Nozzles on 8 in pipe
Nozzles on 6 in pipe
Blow off
To Nozzle Gage when brass pipe was not used.
To "U" gage
Down stream Piez.
8 in. Pipe
8 in Nip.
8 x 6 Nozzle
Flange
Nozzles: $2\frac{1}{2}$ in. & less used on the brass pipe as shown for 4" apparatus. The brass pipe being coupled onto the 4" Nozzle here
To Nozzle Gage, as for above except when brass pipe was used
6 in. pipe
6 in. Nip
6 x 4
Nozzle
$\frac{1}{4}$" Gas pipe
"U" Gage (See elevation)
Plan.
4" Pipe
10 ft. length of pipe
4" Nip
Down Stream Piezom
Bourdon Gage
4 in. Meter
Upstream Piezometer
6 ft. length of 4 in W.I. pipe
Siamese
This 4th line of hose used only with 8" Meter
4-way Hydrant Independent Gates
$2\frac{1}{2}$ inch Hose
$3\frac{3}{4}$" Meter Nozzle pipe (brass)
$1\frac{3}{4}$" Nozzle also 2" & $2\frac{1}{4}$" used here
Nozzles less than $1\frac{3}{4}$ in used here
Nozzle Piezometer on pipe
This gage, with upper one, used for loss, when loss was too great for "U" gage to measure it.
Blow off
$\frac{1}{4}$" Gas pipe
Connection at Down-stream Piezometer
Connection at Upstream Piezometer
connection to "U" gage
Air blow-off
Piez.
To "U" gage
Plan Mercury Pressure Gage
Connection of Mercury Nozzle Gage
Nozzle Piezometer on brass pipe
From Nozzle Piezometer
Blow off cock
Merc. Pot.
To Merc. Gage
Connections of Siamese to 6" x 8" Pipes
upper length of pipe
coupling
For 8" pipe-Bushed 8" to 4"
For 6" " " 6" to 4"
4" Nip
Plan

Plate II.


These piezometers connect to a "U" mercury gage the same as in Salem tests, Plate 1.
Piezometer
Gate
6"
7' 10"
About 25 ft. to measuring tank.
2" Crown Meter
Piezometer
9' 6"
12 ft.
Gate
About 150 ft. to 36" Pump main.
NOTE,–
All fittings except the taper reducers for the 1½" Crown Meter are ordinary pipe fittings.
2" Crown Meter
Piezometer
6" Pratt & Cady Check Valve with leather faced clapper.
6" Gate.
Piezometer
5' 7"
5' 9"
4"
1½" Crown Meter.
Piezometer
6' 7"
"BY PASS" METERING DEVICES TESTED AT PHILADELPHIA

Just up stream from the meters was placed a piezometer with from seven to ten feet of straight pipe back of it, so that the water might enter it without whirls and eddies. Down stream from the meter a similar length of straight pipe was placed for the same purpose, to the end of which was screwed the second piezometer. A quarter-inch pipe was then carried from each piezometer to the "U" tube Mercury gage. With this arrangement the readings of the "U" gage gave directly the loss of pressure between the piezometers. The actual loss caused by the meter was that read from the "U" gage less a slight correction for the friction in the straight pipe between the piezometers. In the few cases where the loss exceeded the range of the Mercury gage, ordinary Bourdon pressure gages were used.

In the Salem and Lowell tests, the quantity of water flowing was measured by meter nozzles, according to the methods developed by Mr. John R. Freeman, (See Trans. Am. Soc. C. E., 1890) as well as by the meter under test. The nozzles used were of the smooth type and varied in diameter of outlet from ½-inch to 5 inches. For very small quantities, ⅛, ¼ and ⅜ inch holes in thin brass plates were used. In the Philadelphia tests the quantity flowing was measured in a large tank with a swinging spout attachment, the depth of which was accurately determined by a hook gage.

Most of the nozzles used had been very accurately calibrated by Mr. Freeman in his experiments at Lawrence and Nashua, so that the quantities by the nozzle may be considered as certainly accurate within about 1 per cent, and probably correct within one-half of 1 per cent. About the same degree of accuracy was obtained at Philadelphia.

In making a test, water was allowed to run for a few minutes before observations were commenced to allow all to come to normal conditions. In most of the Salem tests at a given signal the meter was read and half-minute readings commenced on the "U" gage and on the Mercury nozzle gage. The meter was also read each minute, thus giving a record of the uniformity of flow. At the end of a definite number of minutes, the meter was again read, on signal, and the test stopped. From the average of the nozzle pressures the rate of flow in gallons per minute was computed, and from the average "U" gage readings the loss of pressure corresponding to this flow determined.

In the later tests the exact time in which the meter registered an even number of cubic feet, was noted with a stop-watch, the nozzle measurements being made the same as before. This latter method is the better one as it is free from errors caused by inaccuracies in the graduations of the meter registers, and as it is easier to operate a stop-watch when a dial hand reaches a certain point than to catch the exact reading of a moving meter on signal. With the first method however, the quantities run were generally so large that any errors from these causes would be very small in percentage. When the tank was used instead of the meter nozzles, the rate of flow was found by dividing the total gallons caught in the tank by the time of the test, all other observations being the same as before.

With the ordinary meters the chief point sought was the loss of pressure with various flows, with the meters in various conditions, though the data obtained gave considerable interesting information as to the accuracy with which the meters registered. With the proportional meters the friction loss was also obtained, but in addition the co-efficient by which the reading of the small meter must be multiplied to give the total quantity was carefully determined. In the tests with the tank, the total cubic feet caught in the tank divided by the cubic feet registered by the small meter gives the co-efficient.

RESULT OF TESTS—FRICTION LOSS.

The main results are given in Table I, and are plotted in Plates III and IV. Tables II and III simply give the data of Table I in another form.

From Table I, we find, for example, taking a flow of 500 gallons per minute, or two good, stiff 1⅛-inch fire streams, which is more than a 4-inch pipe would be called on to supply ordinarily the following losses of pressure due to the meter:

In a	4-inch "Hersey"	Meter	40	pounds.
"	4-inch "Crown"	"	31	"
"	4-inch "Lambert"	"	13	"
"	4-inch "Torrent"	"	8	"
"	4-inch "Union"	"	6.4	"
"	4-inch "Gem"	"	4	"
"	6-inch "Gem"	"	1.1	"
"	8-inch "Torrent"	"	0.7	"

TABLE I.

Loss of Pressure Caused by Meters.

Gallons per Minute Flowing Through Meter.	Equiv. No. of 250 Gallons Fire Stream.	Loss of Pressure in Pounds due to the Meter.											
		Current Meter.		Disc M't'r	Rotary Piston.			Current.		Proportional.			Piston.
		4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass 1½ in. Crown.	Worthington.
50	......	...	.	....	0.3	0.5	..	...	....	....	0.1	0.1	1.6
100	.....	..	0.2	0.6	1.4	1.6	0.2	...	....	....	0.1	0.2	6.0
200	. ....	0.8	1.3	2.2	4.9	6.1	1.1	.. .	..	. .	0.2	0.5	23.0
250	1	1.1	2.0	3.4	7.5	9.3	1.7	....	....	0.1	0.3	0.8	34.8
300	......	1.6	2.9	4.8	10.9	13.3	2.5	0.4	0.3	0.1	0.4	1.1	48.0
400	.... .	2.7	5.1	8.2	19.9	25.1	4.2	0.8	0.5	0.2	0.6	1.9	....
500	2	4.1	8.1	12.9	31.2	40.0	6.4	1.1	0.7	0.3	0.8	2.9	....
600	.....	6.1	11.9	18.7	...	....	9.4	1.7	1.0	0.5	1.1	4.4	....
700	.....	8.3	16.4	25.1	...	....	12.8	2.3	1.3	0.7	1.5	6.1	....
750	... 3	9.5	18.9	28.6	....	....	14.6	2.6	1.6	0.7	1.7	7.2	....
800	......	10.8	21.4	....	..	....	16.6	3.0	1.8	0.9	2.0	8.3	....
900	......	13.5	...	....	...	.	20.8	3.9	2.3	1.2	2.5	10.9	...
1000	4	....	...	...	....	...	25.5	4.8	2.8	1.4	3.0	13.9	....
1250	5	...	...	....	..	....	..	7.2	4.5	2.3	4.8	...	....
1500	6	...	...	....	..	....	....	10.0	6.4	3.1	7.1	....	....
1600	......	...	....	....	...	....	....	...	7.3	3.5	8.6	...	....
2000	8	...	...	....	...	....	....	....	...	5.6	..	....	...
2500	10	....	....	...	...	....	....	....	...	....	....	.	...

The Gem, Crown and Hersey meters had fish traps as a part to the meter, so that the losses above includes the trap. The Torrent, Lambert, Union and Worthington meters use a separate trap; they were however tested without traps.

TABLE II.

Equivalent Pipe Losses. (Meters in Normal Condition.)

	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass $1\frac{1}{2}$ in. Crown.	3 in. Worthington.
Approximate feet of new, straight, clean, cast iron pipe that would cause the same loss of pressure as the meter.	45	80	130	310	385	67	180	425	58	122	32	625

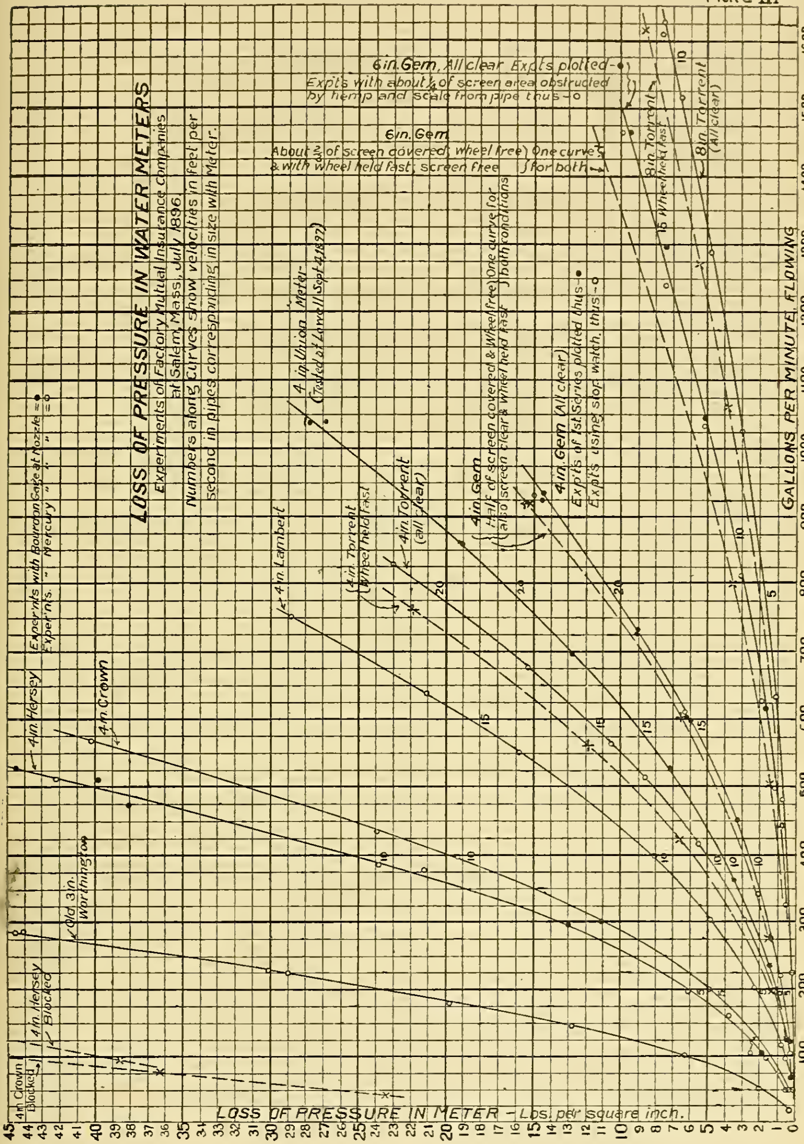
The Worthington Meter was an old one and therefore not fairly comparable with the new clean meters.

TABLE III.

Losses Caused by Meters at Different Velocities.

Velocity Feet per Second in Pipe Size of Meter.	Pounds Loss in Pressure Caused by Meters.											
	4 in. Gem.	4 in. Torrent.	4 in. Lambert.	4 in. Crown.	4 in. Hersey.	4 in. Union.	6 in. Gem.	8 in. Torrent.	6 in. By Pass 2 in. Crown.	6 in. Check 2 in. Crown.	4 in. By Pass $1\frac{1}{2}$ in. Crown.	3 in. Worthington.
5	0.70	1.2	2.1	4.8	6.0	1.0	0.90	1.75	0.3	0.6	0.5	7.5
$7\frac{1}{2}$	1.55	2.8	4.7	10.7	13.3	2.4	2.15	3 92	0.6	1.4	1.0	16.5
10	2.60	4.9	8.0	19.4	25.0	4.0	5.00	7.00	1.1	2 4	1.8	28.0
$12\frac{1}{2}$	4.00	7.8	12.8	31.1	39.8	6.2	5.70	.....	1.8	3.6	2.7	41.4
15	5.80	11.8	18.5	.....	....	9.2	8.00	....	2.5	5.4	4.2	.....
20	10.20	20.4	.....	...	.....	16.0	.....	...	4.4	. . .	8.0	....

Plate III


LOSS OF PRESSURE IN WATER METERS
Experiments of Factory Mutual Insurance Companies at Salem, Mass., July 1896.
Numbers along Curves show velocities in feet per second in pipes corresponding in size with Meter.
GALLONS PER MINUTE FLOWING
LOSS OF PRESSURE IN METER — Lbs. per square inch.
4 in. Hersey
4 in. Crown
4 in. Lambert
4 in. Union Meter
4 in. Torrent (all clear)
4 in. Gem (All clear)
6 in. Gem
8 in. Torrent (All clear)
Old 3 in. Worthington
4 in. Hersey Blocked
4 in. Crown Blocked

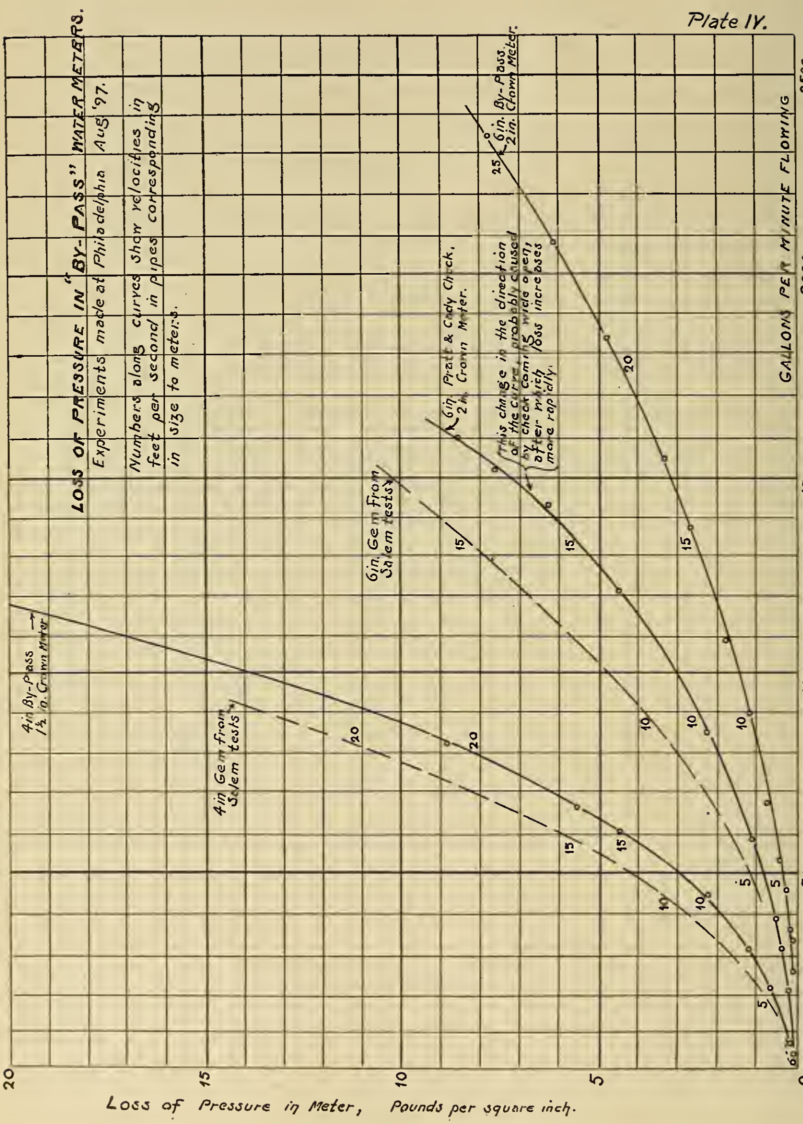


Plate IV.
LOSS OF PRESSURE IN "BY-PASS" WATER METERS.
Experiments made at Philadelphia Aug '97.
Numbers along curves show velocities in feet per second in pipes corresponding in size to meters.
4 in. By-Pass 1½ in. Crown Meter
4 in. Gem from Salem tests
6 in. Gem From Salem tests
6 in. Pratt & Cady Check, 2 in. Crown Meter.
6 in. By-Pass, 2 in. Crown Meter.
This change in the direction of the curve, probably caused by check coming wide open, after which loss increases more rapidly.
GALLONS PER MINUTE FLOWING
0
500
1000
1500
2000
2500
20
15
10
5
0
Loss of Pressure in Meter, Pounds per square inch.

Again, taking 1000 gallons per minute or four good $1\frac{1}{8}$-inch streams, we have the losses as follows:

In a	4-inch "Union"	Meter	25.5	pounds.
"	4-inch "Gem"	"	16	"
"	6-inch "	"	4.8	"
"	8-inch "Torrent"	"	2.8	"

It is to be kept in mind that a 4-inch meter would in practice seldom or never be called on to deliver so much, 1,000 gallons per minute. But these figures are instructive in showing the great difference in friction loss in meters of different types.

In a subsequent test of a number of the meters the moving parts were securely wedged in place so that they could not move, thus representing the conditions when a stick or stone gets into a meter. The results were as below:

In the	4-inch "Gem"	Meter, blocking	increased	the friction	about	10	per cent.
"	4-inch "Torrent"	"	"	"	"	15	"
"	6-inch "Gem"	"	"	"	"	20	"
"	8-inch "Torrent"	"	"	"	"	20	"

The "Crown," "Hersey," "Union," "Lambert" and "Worthington" meters can be blocked in such a position that but little water can pass through them, so that under these conditions they would practically *destroy* a fire service.

These results clearly show up the obstruction caused by meters. It is to be remembered that these figures were obtained with new meters, and everything free and clean; that time would increase the loss of pressure caused by a meter there can be no question. While the losses in the "Gem" and "Torrent" meters are not excessive, it is well to remember that many of the city and town water supplies are at a pressure which can be considered as only moderate for fire streams, therefore, the desirability of avoiding every pound of unnecessary loss in getting the water from the city or town mains to the nozzle of the fire stream, and it is also to be remembered that their apertures are liable to be suddenly obstructed by the gravel stone, stick, eel scale or other foreign material stirred up and brought along with the rush of water caused by the fire draft.

FISH–TRAPS.

In the Salem tests the water used was taken from a 4-way hydrant at the end of several hundred feet of 10-inch yard pipe which had been recently laid—this 10-inch pipe connected with the city mains.

After the first heavy draft of water through this pipe, which occurred with the 6-inch "Gem" meter, when about 1,500 gallons per minute were drawn, *it was found that in this brief period about three-quarters of the surface of the screen in the fish-trap was covered with hemp, pipe-scale and mud*, closing about from one-fourth to one-third of the area.

To get an idea of the effect of partial blocking of the fish-trap, one-half of the screen in the trap of the 4-inch "Gem" meter was covered by a board, in which condition it was found that the loss through the meter was increased about 10 per cent., or about the same as if the trap was free and the wheel blocked. In the 6-inch "Gem" meter, two-thirds of the screen was blocked by a board and the loss thereby increased about 20 per cent., which happens again to be about the same as for the blocking of the wheel.

The area of the screen in the trap for the 4-inch "Gem" meter was about 2.8 times the area of a 4-inch pipe.

The screen for the 6-inch "Gem" trap was about 3.2 times the area of a 6-inch pipe.

The short time which it took when first testing the 6-inch "Gem" meter to obstruct one-third of the screen area, would indicate that in case of the long draft of a severe fire a very serious blocking would be entirely possible; this, however, of course depending much on the care in laying the pipe to keep all obstructions out of it and the frequency with which the mains were thoroughly blown off.

Our experience with screens on the suctions of fire pumps gives further emphasis to this point. While with the ordinary drafts of water—such as when the fire pump is occasionally used at slow speed for boiler feeding or similar work during the time the regular pumps are being repaired—no trouble whatever may be noticed, though the strainer is half covered by grass, gravel or scale; but let the extreme quantity needed for fire fighting be called for and there is dangerous inability to get a full supply.

The fact that obstructions in pipes may remain unnoticed with ordinary drafts and are likely not to be discovered till the heavy draft of a fire calls attention to them, is further illustrated by a

fire which occured some time ago in one of New England's large manufacturing plants, where, after the fire, an important gate was found to be open only about two inches. Again, when the Union Station in Providence burned a year or so ago it was found when, *after* the fire, the cause for weak streams was being looked into, that a main 16-inch gate was shut, the water or at least a part of it, having to reach the fire through a circuitous 6-inch pipe.

With such meters as the "Gem" or "Torrent" where the blocking of the moving parts is not serious, it would be better as far as a fire service is concerned to omit the fish-traps entirely; this is, however, objectionable as without traps there would be danger of drawing a stone or stick into the revolving parts and breaking them every time a large quantity of water was drawn. This, in fact, happened in Salem when testing the 8-inch "Torrent" meter, as no fish-trap was used with it,—a small stone lodging between the guides and the revolving turbine, breaking several buckets. With the proportional type of meter the fish-trap would of course be on the small meter and entirely unobjectionable.

With the above facts in mind, can it be wondered that those who are responsible for the protection from fire of properties whose values often run into the millions, look with serious apprehension at the installation of meters on the fire service pipes.

Drawing from Mr. Freeman's remarks at Hartford, already referred to herein, we do not believe that, except in rare cases, the men who manage the large factory industries of the country would purposely steal water for the sake of saving its cost. That employees may ignorantly or for their convenience, draw water from hydrants, sprinkler blow-offs, or similar outlets on fire systems, is a possibility. In most mill fire systems the piping is laid out in such a simple and direct manner that it is easy for the water works inspector to make himself reasonably sure that no water is being improperly used. If surreptitious use or hidden connection is feared a short $\frac{3}{4}$-inch by-pass may be tapped in around the main gate into the yard, and a $\frac{3}{4}$-inch meter kept set in this by-pass. Then occasionally without warning let the water works inspector shut the main gate for ten minutes and see if the meter moves. This will detect any hidden connection. Moreover, it is entirely feasible to seal the hydrants and blow-off gates on the sprinkler systems, using a lead seal similar to that universally employed on

freight-cars. Such a seal can be easily broken in case of fire, but will prevent any draft of water through the ordinary channels without giving clear evidence of the fact.

Such arrangements as the above necessitate absolutely separating fire supply pipes from those bringing water for manufacturing purposes. In general, however, a pipe much smaller than the fire pipe which may be equipped with any meter the water department desires will furnish all the water used for manufacturing and can be put in at a cost that is entirely reasonable. This is certainly better for the water departments than to use a large meter on the fire main, as a smaller meter allows a closer registering of the quantity used.

ABILITY OF LARGE METERS TO DETECT SMALL FLOWS.

In those few cases where the interest of the water department seems imperatively to require a meter on the fire service pipes, we have heretofore advised the "current" type of meter, such as the "Gem" or "Torrent," and occasionaly find that the superintendents of water departments feel that they are not safe even with these meters from the fear that their large capacity renders it possible to draw considerable quantities through them without registering. To see how serious this matter was we carefully experimented with the large capacity meters to see just where their limit of sensitiveness came. The following results were obtained:

The 4-inch "Gem" meter with 8½ gallons per minute flowing did not register. The wheel was then started by opening some extra cocks thus allowing a larger flow, but when the cocks were closed it stopped again. With 19 gallons per minute flowing the meter registered at the rate of a trifle over 17 gallons per minute. The 4-inch "Torrent" meter with 11 gallons per minute flowing registered at the rate of about 10 gallons per minute. The 6-inch "Gem" meter with 11 gallons per minute flowing, did not register and the wheel did not continue to move at this quantity even after being started by increasing the flow. With 13 gallons per minute flowing, the meter registered at the rate of 4 gallons per minute and with 22 gallons flowing, at the rate of about 19 gallons per minute.

The 8-inch "Torrent" meter with 8½ gallons per minute flowing, registered at the rate of 2 gallons per minute. With 20 gallons per minute flowing, at the rate of about 18 gallons per minute. These

tests were made with the small orifices in thin brass plates, pressures at the orifices being in the neighborhood of 60 pounds.

These results show that the amount of water drawn, where the pressure is good and the service pipes are of liberal size, by an ordinary $\frac{5}{8}$-inch sink tap, or by an ordinary garden hose with $\frac{3}{8}$-inch nozzle, would be registered with tolerable accuracy by a new 6-inch "Gem" or new 8-inch "Torrent" meter, but that about half of this rate of flow could be drawn without registering. A discharge of a single automatic sprinkler would be well registered.

The piston and disc meters can detect and measure considerably smaller flows. The 4-inch "Union" meter was the only one which was specially experimented with as to sensitiveness. With this meter the flow through a $\frac{1}{8}$-inch sharp edged hole in a thin brass plate under 90 pounds pressure, or about 2.8 gallons per minute was the lowest which would move the meter. The meter recorded about one-half of this flow, the other half being leak. With a $\frac{3}{8}$-inch orifice, under 5.4 pounds pressure, giving 5.7 gallons per minute, the meter was about 16 per cent behind in quantity. With the same orifice as 15 pounds, giving 9.6 gallons per minute, the meter was about 5 per cent slow.

With the 4-inch "Lambert," "Crown" and "Hersey" meters, $8\frac{1}{2}$, $14\frac{6}{10}$ and $21\frac{5}{10}$ gallons per minute, respectively, were the smallest quantities drawn, the meters registering these flows satisfactorily.

We made no tests on the "Venturi" meter, as this has been very fully reported upon by others. The loss caused by this meter is so small as to be practically unobjectionable. The meter may, however, introduce an obstruction if the brass lining of the throat is not made long enough, from tubercles forming on the unprotected iron near the throat and choking the passage. This trouble can of course be easily remedied by extending the lining on both sides of the throat for a liberal distance. Large "Venturi" meters, it is understood, cannot satisfactorily measure very small flows.

In the Philadelphia tests the by-pass arrangements experimented on, were those which the Philadelphia Department had found after a good many experiments, gave the best results. Their data being freely open to us, made it possible to quickly come to conclusions as to these devices, thus saving us a large amount of experimenting. The results were as follows: With the 6-inch by-pass and 2-inch

"Crown" meter it was found impossible to keep the meter moving with a total flow less than about 250 gallons per minute. With a 4-inch by-pass and 1½-inch "Crown" meter, about 45 gallons per minute was the lowest quantity we succeeded in registering. These results cannot be considered satisfactory.

Table IV and Plate V give the co-efficients by which the readings of the small meter must be multiplied to give the total quantities, and show that with larger quantities these devices can measure with tolerable accuracy. If with the 6-inch by-pass the co-efficient be taken as 29 the greatest deviation from the co-efficient, found experimentally, would be about two, over a range from 500 to nearly 2500 gallons per minute. This would mean at the worst point an error of about 6½ per cent in the quantity measured.

With the 4-inch by-pass with from 200 to 1800 gallons per minute flowing, the average co-efficient would be about 16, the maximum found in the experiments being a trifle over 17, and the minimum a trifle over 16. The maximum error being about 6½ per cent as before.

As the whole idea of the proportional meter is to create a loss of pressure between the points of connections of the small meter, it was thought that possibly the check valve, ordinarily necessary in a factory fire service to keep the fire pump water off of the public mains, might be used instead of a by-pass to cause this necessary loss of pressure, thus making unnecessary any additional obstruction. The use of a check valve for this purpose was also suggested by Mr. Crandall in his paper before this association, read February 10th, 1897.

With a 6-inch Pratt & Cady check valve, with leather faced clapper and a 2-inch "Crown" meter in a by-pass around the check, we found about 45 gallons per minute, the lowest flow which would keep the small meter running. With this flow the co-efficient was about four. It rose rapidly to about 23 at 300 gallons per minute, the average being then about 22 from 300 to 2500 gallons per minute. The maximum co-efficient found was 23½, the minimum 20½, giving curiously about 6½ per cent as the maximum error as with plain by-passes. While these results are not especially satisfactory, it would seem that the idea has very hopeful prospects of development.

TABLE IV.

Co-efficients for By-Pass Meters.

Rate of total flow in Gallons per minute.	Co-efficients by which readings of small meters must be multiplied to give total quantities passing.		
	6 in. By Pass. 2 in. Crown.	6 in. Check. 2 in. Crown.	4 in. By Pass. $1\frac{1}{2}$ in. Crown.
10	....	...	...
15	....	....	....
20	....	....	....
30	....	....	....
40	....	4.0	34.5
50	....	6.0	28 0
75	....	6.0	22.5
100	....	8.0	20.8
150	....	12.2	16.5
200	....	16.8	15.5
250	38.0	20.0	15.5
300	35 0	22.7	15.7
400	31 3	23.1	16.4
500	30.8	22 9	16·5
600	30.6	22.9	16.1
700	30 0	22.0	16 1
800	29 0	21.1	16.5
1000	28.0	21.0	16.6
1200	28.2	21 3	16.7
1400	28.8	21.6	16.8
1600	29.3	21.1	17.0
1800	29.5	21.2	17.1
2000	29.3	21.4	....
2200	29 3	21.6	...
2400	29.5	21.8	....
2600	....	22.1	....

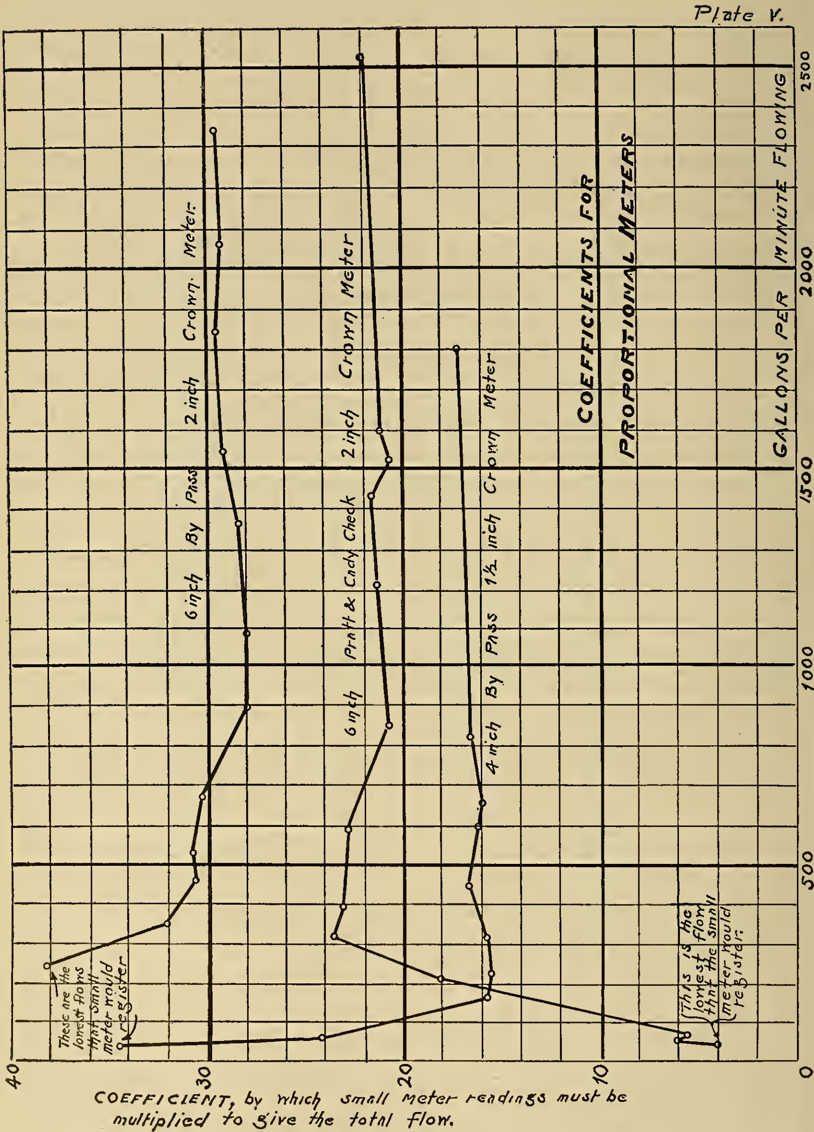


Plate V.
COEFFICIENTS FOR
PROPORTIONAL METERS
GALLONS PER MINUTE FLOWING
2500
2000
1500
1000
500
0
6 inch By Pass 2 inch Crown Meter
6 inch Pratt & Cady Check 2 inch Crown Meter
4 inch By Pass 1½ inch Crown Meter
These are the lowest flows that small meter would register
This is the lowest flow that the small meter would register.
40
30
20
10
COEFFICIENT, by which small meter readings must be multiplied to give the total flow.

If in some way *which could not possibly endanger the full opening of a check valve* a slight *initial stick* can be given to the clapper, *all* the water at small flows would be forced through the small meter, thus bringing the sensitiveness of the whole device down to that of a 1 or 2-inch meter of the best type. With large flows, the check would open, and a quantity would be measured on the proportional plan. Mr. Freeman some years ago proposed a check valve with a weighted clapper for this purpose, but has not found time to work out the idea in practical shape to his satisfaction, but it appears entirely practicable.

In Mr. Crandall's paper it is suggested that the spindle of the clapper be carried through the valve casing, and an outside weighted lever attached, with the weight so arranged that it will be thrown off when the valve opens. The possibility of dangerous sticking of the spindle, or of the external lever becoming carelessly blocked by some obstruction in the valve pit, would make this arrangement a little open to suspicion. It would seem, however, that these dangers could be gotten over and a satisfactory solution of the problem found after due study, and we shall be much pleased if some member of this society will work out the details of such a device.

In most fire systems it is illegal to draw *any* water except for fire, when the quantity used is not cared for, without notifying the water department. It would, therefore, seem that the check valve arrangement would put about as useful information into a superintendent's hands as if he could swear to the exact quantity used, i. e., if he was sure of the *fact* of sinning, the *degree* of it would be of minor importance.

This device, besides its action as a *detector*, would, however, give some idea of the degree, though it has one curious quality in which it resembles the general idea of the working of our common law in that it jumps hardest on the man who does not steal enough. If, for instance, only a small quantity is taken, i. e., not enough to overcome the initial stick of the clapper, and then the water department figures the bill, using the average co-efficient of 20 or 30, the mill will certainly pay a fine rather than a water bill, while if a large quantity was stolen, the fine element would disappear.

This might lead to disputes, but as the law had been broken anyway, the offending one would have little ground to stand on. The weighted lever arrangement, moreover, with the falling off weight

mentioned by Mr. Crandall, suggests the possibility of some sort of a recording device which would show if the clapper moved from its seat.

Such an arrangement would seem to give us a device absolutely unobjectionable to insurance companies, but one which would appear to give complete protection to water departments.

The use of the meter nozzle gave a means of learning the average accuracy of the various meters tested. In general, it was found that meters of the current type, with flows slightly above the minimum mentioned, measured the water within from three to four per cent of the truth, and often closer, though occasionally a somewhat larger deviation would be found. With the disc and piston meters tested the average accuracy was from one to two per cent. These results would seem to be good enough when measuring a liquid no better than water.

CONCLUSION.

In conclusion, our position on meters, with the devices *now* obtainable in the market is this :

1st. We should earnestly advise that *every other means* for safe guarding the interests of the water department be exhausted before resorting to meters.

2d. Where meters are unavoidable, we should urge the use of the current type, such as the "Gem" or "Torrent."

(a) Because the loss of pressure caused by these meters is moderate.

(b) Because if their moving parts become stuck the friction loss is not seriously increased.

3d. We do not consider the ordinary types of disc or piston meters at all suitable for fire pipes from the fact that they can almost completely stop the flow, if their moving parts become blocked.

4th. In cases where meters must be used, we should advise that they be placed on a by-pass, with a gate in the straitway connection. This straitway gate should be provided with an indicator post, and if possible, the meter should be so placed that this post will be in a conspicuous location. It is also a good plan to put gates in the by-pass, on each side of the meter, so that it may be examined or repaired without shutting off the fire service.

DISCUSSION.

The President. The paper is now open for discussion. Is there any one who noticed anything in the paper with which he did not quite agree, or is there some meter man who can tell us how to remove the obstruction, or possibility of obstruction, that exists in connection with his particular type of meter? It seems as though there must be something to be said in the discussion of this paper, which will be of interest to us all.

Mr. French. Mr. President, I should like to learn the general opinion of the superintendents as to how much value this sort of detector idea would have. That is, if you had an arrangement which would simply give you the information that *some* water had been drawn, wouldn't that, in a great many cases, be all you would care to know? This is a problem on which we find you have a good deal more to say when we come to meet you individually, and want certain things done, than you seem to be willing to say this afternoon, but we would like to get what ideas we can from you now, for it may help us later on. We imagine that with the attempts that now seem to be made everywhere to reduce waste, perhaps the fire service pipe would be jumped upon about as soon as anything, although, as I have said, our experience would indicate that they are not a very great cause of waste. We want to get at just what is really necessary for the protection of that sort of a service. You see our idea of the subject, anyway.

Mr. Fish. Is it a fact that fire service pipes in New England are generally metered?

Mr. French. We have very few meters on fire pipes, and have always taken the ground strongly that they should not be there; but we do find every now and then a desire, and perhaps it is increasing, to put meters on, and occasionally we find a place where it is impossible for us to convince the superintendent that a meter should not be put on. A very small percentage of our factory sprinkler and yard hydrant fire services are metered, probably not one in twenty, but still there are enough to make it somewhat of an important question with us.

Mr. Fish. It is novel to me that they have meters for fire services.

Mr. French. Perhaps I should explain that, the properties which the Factory Mutuals are principally interested in are similar to the large mills at New Bedford, Fall River, Lowell and Lawrence, where they have a large mill yard, and very often an 8, 10 or 12-inch connection, from the city service right into the yard, and a complete system of fire hydrants and automatic sprinklers, independent of the supply for manufacturing purposes. Check valves are placed in these connections so that the mill fire pumps cannot pump back into the public mains. It is the general custom for the mills to allow the water works inspector to enter the yard at any time, and to see just exactly what is going on. In some cases, where there seemed to be cause for suspicion, the water department has sealed all the blow-off gates, each hydrant, and the valves controlling the sprinklers. It is understood, of course, in these cases that the fire system is entirely separate from the supply for mill use, so that excepting in case of fire there is no occasion for any draft from it whatever.

The President. Is there any superintendent here who has meters on fire service pipes, who would like to say something on this subject? I don't like to call upon anybody by name, but I will ask Mr. Walker if he has ever had any experience in that direction. (Applause.)

Mr. Walker. As far as fire pipes are concerned, I confess that sometimes one feels as if he would like to have them metered. For instance, you have a mill where there are pipes for fire purposes only, they will take the city water to fill their boilers with occasionally, and use it generally as they see fit. We had one case in Manchester where, unfortunately, their reservoir was lower than ours, and on one occasion when something ailed their pumps, they opened the gate and filled up their reservoir from ours. There wasn't any meter in use there. Where the supply comes right from the city, I am satisfied that there ought to be something done to meter those places. The insurance men want a 12-inch pipe for a 50-foot mill. (Laughter.) They want to cover it all over with sprinklers; naturally, they don't want any loss. They are very anxious, and they have a great deal of information on these subjects, and they tell us just how big a pipe is needed for this and that, wherever they have any insurance on property. (Laughter.)

A gentleman came to me last year and said he was going to try the hydrants in his yard and wished me to come down or send a man. He was a pretty good sort of a fellow, and he wouldn't open them without my permission. He said, "I have made up my mind I am not going to put anything new in, and if the insurance company won't insure the mill as it is now, it needn't insure it at all, and I will do it myself." These insurance men come around and look at your plant and tell you what you ought to have done, so really the superintendent hasn't much to say about it. They generally take all the measurements, and tell the superintendent what kind of pipe they want in such a street, where a new depot is going up, or a new mill, or something of that kind. I am not prepared to talk on this subject, but I should really like to talk on it about half a day (laughter), because I have been afflicted somewhat by these insurance fellows. I guess, however, I won't air my grievances this afternoon, because I haven't got in very good shape what I would like to say. But I am satisfied of this much, that some kind of a meter—I shan't recommend any particular kind, for they all go back on me at times, as I have said before—but I am satisfied that there should be some kind of a meter on all fire services so that the mills can't steal the water. The bigger the company the more it will steal. (Laughter.)

The President. I would like to ask Mr. French if he does not consider that there is a large loss of water on account of fire sprinklers, which cannot be attributed at all to fires? For instance, in a factory in Lynn I have understood that on an average nine sprinklers burst in a week; and whenever a head bursts it necessitates the running of the full amount of water contained in the pipes at times. And it does seem to me that there must be a large use of water on account of these fire sprinklers that we don't know anything about. It goes into the general consumption, the 40 or 50 per cent of water we pump that doesn't do anybody any good. And while this does not really enter into the question of the use of meters on the fire service generally, if we had meters on the sprinkler service they would pay for the amount of water that they use when there is no fire, and which really is quite an important factor, in my opinion, in the water works supply. I would like to ask Mr. French if it is not a fact that there is a large amount of water wasted, owing to the irregular working and repair of these points?

Mr. French. In answer to Mr. Haskell—I assume he means water wasted by the breaking open of an automatic sprinkler when there is no fire.

I am sure Mr. Haskell has been misinformed about the danger of heads opening when there is no fire, and that nine breaks in the whole city of Lynn for a year would be more likely the case. Moreover, of these breaks, many would be from accidental blows and therefore instantly discovered, and very few would open of their own accord. In the properties insured by the Mutual companies there are over two million (2,000,000) sprinkler heads, but our experience is that the loss from water damage is almost nothing. We do have sprinklers break open, but the loss caused is very, very small, and considering the immense number of sprinklers that we have, the breaks are very, very infrequent. I know in Lynn, because my home is there, there have been one or two, perhaps more unfortunate cases of sprinklers breaking in shoe factories, and the break not being discovered for some time. But in the Factory Mutual work every plant has a watchman, often more than one watchman, so that the bursting of a spinkler is generally discovered promptly. In fact, so low has been the loss from sprinklers that to allay the fears of some of the mill people, when asked to put sprinklers over valuable parts of their plants, two of the largest Mutual companies have taken up sprinkler insurance, that is, they insure against water damage from the accidental bursting open of sprinklers and fire protection pipes and have found the actual losses to be insignificant. It is probably within the truth to say that less than one sprinkler in fifty thousand of the better types breaks open accidentally in the course of a year. I am positive that the waste of water from the breaking of automatic sprinklers is of no importance whatever.

The President. As I understand the value of an automatic sprinkler, it is simply to effect one purpose, and that is to stop a fire right at its inception. These sprinkler heads are distributed through the factory, and if the heat at any one point gets above a certain degree, the sprinkler operates. Immediately a certain amount of water escapes, but no greater amount of water passes through the pipe than can pass through one sprinkler, which, in the case of a 6-inch meter, would be an almost infinitesimal amount.

My object in making this explanation is this: I think all super-

intendents will agree with me that it certainly would be proper to pay the city for all the water used to keep these pipes in order. I do see force in the argument that we ought to supply these sprinklers with water for fire purposes, the same as we supply water to the hydrants for fire purposes. Where a city gives water for fire purposes to a hydrant free of charge, perhaps they might be expected to do so to fire sprinklers, from the fact that a small amount of water used by the fire sprinkler to extinguish a fire, would save a large amount which would have to be used later in case the fire broke away. But the principal objection I saw, or the two objections I saw, as the paper was read, which the sprinkler people make to the use of meters on their pipes, were: first, that they reduced the pressure of the water; secondly, that it might be possible for an obstruction to stop the flow of water entirely. Now it occurs to me that there is little water used by a fire sprinkler until its point of efficiency is passed. I consider that a fire sprinkler is a very good thing until the fire department gets there; the moment the fire department gets there it is worse than useless, it does not help the fire department a great deal in putting the fire out, and, consequently, there are only, perhaps, one or two, or three, or at the most, five minutes, when the fire sprinkler is expected to do any work. If that is the case, with the amount of water that can flow through these one, two, three, four or five points, it would not effect the efficiency of the sprinkler at all to have a 4-inch or a 6-inch meter on the supply. That is the way it looks to me, but I should like to get a little information from Mr. French in that direction.

Mr. French. There is no doubt whatever that the introduction of automatic sprinklers lessens the total consumption of water for fire purposes if you have a small brief fire to fight instead of a large fire lasting for hours. The amount of water drawn by the ordinary automatic sprinkler at 60 pounds pressure is in the neighborhood of 45 gallons a minute with no allowance deducted for pipe friction, but under ordinary conditions of pipe friction the discharge from a dozen sprinklers equals the discharge from one hose nozzle. Now it is true, as Mr. Haskell said, that in a great many cases one or two sprinklers open and put out a fire. When that happens the fire department generally finds very little to do. In our fire reports, averaging more than a fire a day, we are all the time finding fires reported where two or three heads have opened and the fire has been

extinguished. Perhaps the department has had to put on a hose stream to get into a corner somewhere, but the fire was practically put out by the sprinklers.

Now in small buildings or with ordinary contents, it is true that there would commonly be only a comparatively small number of heads open. But in cotton mill work the tendency is towards very large areas. In New Bedford there are mills five or eight hundred feet long, and 125 to 140 feet wide. In such a mill it is almost impossible to reach the center with a fire hose stream, so that in such places we look upon the automatic sprinklers as our main reliance for putting out a fire, and we feel that there is always a chance that perhaps 50 or 100 heads may open. We have had several fires in Picker rooms where twenty-five or thirty sprinklers opened in the first few minutes of the fire, and before hose streams could be put on. This was not where the pressure was feeble but where it was especially strong and able to supply large quantities without much reduction in the mains. In these cases the sprinklers did hold the fire and practically extinguished it. The only reason that so many heads opened was the quickness of the spread of the fire over loose, combustible stock. We have also had cases where seventy-five or more heads have opened.

Besides the wide buildings, there are high buildings which are sometimes quite wide besides, five or six stories and 100 feet in width not being uncommon. Here a fire in the center of the top story is very inaccessible to hose streams, so that the sprinklers are the chief reliance.

I think it will be evident to all, that any meter which in such cases cuts off several and often many pounds pressure, may seriously lessen the efficiency of the sprinklers and greatly increase the chances of a serious fire. Moreover, perfectly possible obstructions may increase the normal losses greatly or even cut off the supply entirely with some meters.

Our whole tendency is toward more liberal pipe sizes for sprinklers, meaning a chance to use larger quantities of water and within a year or two, Mr. Freeman, has advised, and there has been adopted by our companies, a schedule of more liberal pipe sizes, so that where eight or ten sprinklers are in line the most distant heads will get a good supply of water; while with the old sizes, if you open that number of heads in a line, the most distant ones will absolutely fail to get enough water to do more than drip a liberal drip.

Under these conditions you see the absolute necessity for a first-class supply. And then, remember also, that the sprinklers are the things which are working while the fire is being discovered, that is, before it is discovered, or while the department is getting there; and you will see why we feel more and more desirous, as time goes on, to make the sprinklers efficient whether few or many open at the start. In fact, our whole experience is that the very low cost of insurance in the Mutual companies is in a very large measure, due to the good work of automatic sprinklers.

THE PRESIDENT. I would like to ask Mr. French, allowing that meters are to be used, if it would not be possible to use a proportional meter, and use that with perfect safety, as far as reducing the pressure would go on the main flow of the water, even if some obstruction got into the proportional meter?

MR. FRENCH. I am very glad to have that point brought out. The proportional meter comes about as near not being a meter as anything we know of, and therefore it is the thing we like better than anything else. It, of course, puts no positive obstruction in the pipe, simply creating a little friction which operates the little meter. Now the question is, would you, superintendents, be satisfied with the proportional meter? It seems to me, as I understand your position, and I should very much like light on this point, that what you fear is the stealing of the water through the fire service pipes, either purposely or through misunderstanding. Well, now, if that is what you want to guard against, it is not going to be 500 gallons a minute, but perhaps 10 gallons a minute, or 15, or 20, and I should suppose that what you needed was something which would absolutely tell you about that thing. When it comes to larger quantities, they would hardly be used anywhere except for fire purposes, and you don't care about those. You don't charge a man for water for fire purposes, because if he don't put a fire out you have to go there and do it through another department of your government. The important thing is to prevent the stealing of water, and that is where the check valve idea seems to present a good many possibilities.

The check valve meter can be a cheap device. It gives you a proportional meter, and if you get something which will hold the clapper on the check down tight until there was a flow of 15 or 20 or 50 gallons a minute, you force all your water through the little meter and measure it accurately, but when the larger flow comes, as

from a fire draft, the check will open, and everything go on freely under ordinary conditions, or with the loss of only one or two pounds pressure, and no chance for clogging small orifices or stopping the flow entirely. Your little meter in the by-pass will meanwhile work on the proportional plan, although not recording the whole, but under those conditions you wouldn't care so much how much water was drawn. Ordinarily that little initial sticking of the check valve caused by weighting it would throw all the water to the small meter, and if you had a 10-inch service pipe, that some insurance man had somehow or other got laid into a large factory yard, you would be absolutely metering it. That is, you would have a meter on there which would be just as sensitive as if you cut that 10-inch pipe right off and put a 1-inch meter in its place. It would seem as if that would give you just the information you want, for you could go to a man and say, "You have no right to use this fire service, for you haven't had a fire, but your meter shows you have been drawing the water." He says, "How much have I drawn?" You can say, "That is not the question. You are not allowed to draw any," or you could state that at least the amount drawn was the full amount registered, and that if he had drawn it at a rate rapid enough to exceed the capacity of your (let us say) 1½ inch disc meter he had drawn in excess of the registry. And it would seem to me in that way you could keep guard over the fire system, that your interests would be absolutely looked out for, and that would be one point in your system that you knew was safe.

Mr. Fuller. I would like to ask Mr. French whether a large number of small meters would not give more satisfactory results than one large meter, whether the registration would be any better?

Mr. French. Of course if you had a 6-inch pipe and put in eight or ten 2-inch Disc meters you would reduce the friction to a point where even an insurance man could hardly object to it. And, moreover, by having so many openings you would, of course, very much reduce the danger of the meter becoming stuck. That is, it is very improbable that four or five would get stuck at the same time. When it came to measuring the small flows, and that is the thing I suppose you are most interested in, it would seem to me you would get no more sensitiveness than with a big meter, for the water would simply gradually find its way through each of the meters, and probably none of them would register much of anything.

SINKING FUND TABLES.

BY F. L. FULLER, C. E., BOSTON, MASS.

[*Read Sept. 8, 1897.*]

As the payment of many water works debts is provided for by means of a sinking fund, it may be interesting to show how the amount required for yearly payments may be determined.

A sinking fund is ordinarily made up of annual contributions or payments, which with their accumulated interest, shall, at the end of a certain period, pay the debt for which the fund was formed.

It is evident that the longer the term which the sinking fund has to run, or in which to mature, the smaller the annual payments will be, both on account of more numerous payments and of larger accumulations of interest. Thus the annual contribution which will be necessary to pay a debt of $10,000 in ten years at four per cent, compounded semi-annually, is $799.08, while to pay the same debt in thirty years requires a yearly payment of only $170.24.

The following table shows what one dollar amounts to at the end of each six months up to the end of four years, when put at interest at four per cent and compounded semi-annually:

At time of deposit	$1.000
" end of 0 years and 6 months	1.02
" " 1 year	1.0404
" " 1 " and 6 months	1.061208
" " 2 years	1.08243216
" " 2 " and 6 months	1.1040808032
" " 3 years	1.126162419264
" " 3 " and 6 months	1.14868566764928
" " 4 years	1.1716593810022656

A similar table can be computed for any other rate, compounded either annually or semi-annually.

At the present time, four per cent, compounded semi-annually, is the common rate of interest for sinking funds.

From a table similar to the above, and computed for a period of thirty years, and carried out to a proper number of decimals, can be constructed a table showing the result of depositing or paying in one dollar each year and allowing it to go on interest at the rate of four per cent, compounded semi-annually.

The following tables are constructed for the period of 30 years, which is as long as many sinking funds run.

From this table it appears that one dollar paid in at the beginning of 30 years, amounts to $3.28103 at the end of that time. One dollar paid in at the beginning of 29 years amounts to $3.15362 at the end of that period. One dollar paid in at beginning of 28 years amounts to $3.03117 at the end of that time, and so on till the last payment, which amounts to only $1.0404, because it is on interest only one year.

If we add the amounts together, we find that the thirty payments of one dollar, with the accrued interest, amount to $58.74219. Twenty annual payments of one dollar, with accrued interest, amount to $31.11002. Ten annual payments of one dollar with accrued interest, amount to $12.51435.

This is shown in the second column of the table, which is obtained from the first by successive additions.

Now it is evident that if one dollar paid in each year, and immediately put at four per cent interest, and compounded semi-annually, produces at the end of thirty years $58.74219, that to produce $125,000 at the end of the same time, the annual payment must be equal to $125,000 divided by $58.74219, or $2,127.94.

To produce $1,000 at the end of 30 years, the annual payment must be equal to $1,000 divided by $58.74219, or $17.0235.

To produce $1,000 at the end of 20 years, the annual payment must be equal to $1,000 divided by 31.11002, or $32.1440.

The necessary annual payment to produce $1,000 in any given number of years is given in the third column of the table, which is obtained from the second, by dividing 1,000 by the corresponding number in that column.

WELLESLEY WATER WORKS.

Table Showing Debt and Annual Contribution Required for the Sinking Fund.

F. L. Fuller, Civil Engineer, Boston.

Year in which Debt was Incurred.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Amount of Debt.	Annual Contribution Required.	Total Annual Contribution Required
1885	$125,000	$2,127.94																													$2,127.94
1886	"	"	$5,000	$453.38	$4,000	$319.63	$5,000	$355.61																							3,256.56
1887	"	"	"	"	"	"	"	"	$7,000	$403.64	$5,000	$160.72																			3,820 92
1888	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$321 44																	4,142.36
1889	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$10,000	$321.44															4,463.80
1890	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$6,000	$192.86	$6,000	$179.60											4,836.26
1891	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$6,000	$179.60									5,015.86
1892	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"									5,015.86
1893	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$18,000	$578.59							5,594.45
1894	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$9,000	$289.29					5,883.74
1895	"	"			"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$15,000	$482.16			5,912.52
1896	"	"					"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	$9,000	$289.30	5,882.19
1897	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1898	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1899	"	"							"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1900	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1901	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1902	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1903	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1904	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1905	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1906	"	"									"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1907	"	"											"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1908	"	"													"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1909	"	"															"	"	"	"	"	"	"	"	"	"	"	"	"	"	
1910	"	"																	"	"	"	"	"	"	"	"	"	"	"	"	
1911	"	"																			"	"	"	"	"	"	"	"	"	"	
1912	"	"																					"	"	"	"	"	"	"	"	
1913	"	"																							"	"	"	"	"	"	
1914	"	"																									"	"	"	"	
1915																													"	"	

The number of years the debt has to run is shown by the ditto marks (").

Years.	Amount obtained by compounding $1 semi-annually, at 4 per cent.	Amount obtained by paying $1 annually and compounding semi-annually at 4 per cent.	Annual payment required to produce $1,000 when compounded semi-annually at 4 per cent.
1	1.04040	1.04040	961.1688
2	1.08243	2.12283	471.0692
3	1.12616	3.24899	307 7880
4	1.17166	4.42065	226.2111
5	1.21899	5.63964	177.3163
6	1 26824	6.90788	144.7622
7	1.31948	8.22736	121.5457
8	1.37279	9.60015	104.1650
9	1.42825	11.02840	90.6750
10	1.48595	12.51435	79.9083
11	1.54598	14.06033	71.1221
12	1.60844	15.66877	63.8212
13	1.67342	17.34219	57.6628
14	1.74102	19.08321	52.4021
15	1.81136	20.89457	47.8593
16	1.88454	22.77911	43.8999
17	1.96068	24.73979	40.4207
18	2.03989	26 77968	37.3417
19	2.12230	28.90198	34.5997
20	2.20804	31.11002	32.1440
21	2.29724	33.40726	29.9336
22	2.39005	35.79731	27.9351
23	2.48661	38.28392	26.1206
24	2.58707	40.87099	24.4672
25	2.69159	43.56258	22.9555
26	2.80033	46.36291	21.5690
27	2.91346	49.27637	20.2937
28	3.03117	52.30754	19.1177
29	3.15362	55.46116	18.0306
30	3.28103	58.74219	17.0235

A water works or town debt is generally made up of several issues of bonds or notes. These bear different dates, are for various amounts, and run for different periods of time.

The contribution for each issue must be computed separately and the sum of these contributions will be the annual contribution required to form a sinking fund capable of meeting the various obligations as they become due.

DISCUSSION.

THE PRESIDENT. It is well known to all of us that water works men know more about almost anything connected with water works than the financial part. The financial part of the department, the control of the sinking funds and everything in that connection, is usually turned over to some commission or some members of the

city government, and, while I suppose they always exercise good judgment in the way they handle the sinking funds, it has often occurred to me as very remarkable that it is so seldom they invest any of their funds in buying their own city's bonds. Most cities have to issue bonds, have to hire money, and I have often thought it would be a wise plan for a city to borrow of itself.

Mr. Fuller. I would like to say in that connection, Mr. President, that the sinking fund of the town of Wellesley amounts to about $60,000, and that is entirely invested in the securities of the town of Wellesley. Of course it may not be possible to continue that practice, but, as Mr. Haskell has said, I think it is a good one.

Mr. Smith. I have had some experience as water commissioner and also as water superintendent in one of our small towns, where we have a debt of $75,000. The difficulty of investing the amount of money which is required for the sinking fund, is one which is somewhat perplexing. We could not buy securities with it, because the amount was so small. We have found that the best way, in order to secure compound interest on it, is to deposit it in the savings bank. In that way we have no trouble whatever; there is no money to be handled, we put in each year just the amount of money we calculate is required to make the exact deposit in the savings bank, and we let it remain there until our bonds become due, and then we draw from the savings bank whatever money is required to pay them.

As I say, we have a debt in our town of $75,000. I was very strongly advised against establishing a sinking fund at all, and it was recommended that it would be very much wiser to have annual payments, doing away with a sinking fund entirely and paying so much a year. The difficulty there was we would have to divide our whole debt up into sums of money so small that capitalists would not care to purchase the securities. It was necessary to have our debt divided up into thousand dollars. We finally made an arrangement so our debt should become due in installments of five years each—a certain number of bonds—the first five years, the next five years a larger number, and so on. The last five years of the thirty,—they were divided into six different series,—quite a large sum would become payable, but the interest, of course, is constantly decreasing with the debt. Our act of incorporation required us to establish a sinking fund, and the fact that the bonds were not to be paid

in annual payments created a necessity for a sinking fund, and in order to provide means for paying the installments as they became due, we deposited our money in the savings bank.

Mr. Gilbert. In our town we have placed the sinking fund in our own water bonds wholly. We began in that way and have always kept it up, so our sinking fund consists of our own water bonds. They pay four per cent and we have taken them at par.

Mr. Fuller. I would like to ask Mr. Smith what rate of interest he gets?

Mr. Smith. We usually get four per cent, and our bonds bear interest at four per cent. I ought to say, perhaps, what I omitted to say, but my friend has brought it out by the remarks he has just made, that we virtually invest in our own bonds, because every five years we take up a certain number of the bonds. Then the next five years we have to make a deposit in the sinking fund large enough to cover the interest on those bonds we have redeemed.

Mr. Beals. I have had a little experience with sinking funds and with water debt, but not in the line of the practice of the gentleman who spoke last. I do not understand how he can get interest from a savings bank on more than $1,600, for our Massachusetts savings banks can only receive a deposit up to one thousand dollars and pay interest on sixteen hundred dollars. If they pay on more than that I suppose they are liable to be called to account by the bank commissioners. We have in our town a debt of the size he mentioned, $75,000. We commenced at first by making it payable in blocks of a certain amount at the end of each five years. After running a little while we found just that difficulty of finding an investment for our sinking funds. The savings bank would take only a thousand dollars, and we could not find investments, and we began to see thousands of dollars piling up. Now to an average water man five thousand dollars is a big sum, I mean to those of us connected with the smaller works, and we saw that the whole thing was rather a menace. There was a temptation, an itching desire, perhaps, to handle large amounts of money. And right here I may say it seems to me that the paying of a debt with a sinking fund is like constituting ourselves bankers. It is doing a double business to accomplish a single purpose. That is we reckon how much we owe, and how much we are getting in our sinking fund, and there are two funds piling up.

After running one year we found there was this temptation, the difficulty of finding investments, and the risk of having some board or commission handling the sinking fund, and necessarily some salary to be paid to somebody to handle it, which would be an expense. Our bonds were all held by one savings bank as an investment. So we obtained the permission of our fire district which owns the works, and of the bank holding our bonds, to alter our times of payment, and we made thirty different bonds, payable in different sums in the thirty years. When our act was passed we were required to establish a sinking fund, and at that time we voted to establish a fund to which we would contribute every year an amount sufficient to pay the bonds maturing at the end of each five years. We changed our bonds so that we made a bond payable every year. The first five years of the thirty we paid a thousand dollars a year. Then at the end of that time, if we had paid five thousand dollars we saved two hundred dollars in interest, and we calculated our works would be increasing in the meantime, and our receipts increase, so that in the second five years we could pay fifteen hundred dollars each year, and the third five years two thousand dollars, and I think the fourth five years we jumped to three thousand dollars, and then thirty-five hundred dollars, and then four thousand. We find we can keep a deposit of about a thousand dollars in the savings bank, but we hardly need to. We are on our twelfth year now, so we are required to put two thousand dollars into the sinking fund each year. There are two times in the year when a certain extra receipt comes to us, and we put that into the sinking fund. The first of September our bonds become due, and we draw an amount equal to the bond, and have something left all the time. Our sinking fund is never very large, and there is not the temptation for any board of officers handling a big sum of money, and we, as water commissioners and trustees of the sinking fund cannot get away with a very big sum if we wish to. We have protected the district, and got the sinking fund into a state of annual payments, where we handle only just about the money that we earn, and save, and expend towards the payment of our debt. The ordinary sinking fund is just like an individual hiring twenty thousand dollars for a certain purpose, and then going ahead and trying to lay up twenty thousand dollars somewhere else to pay what he has borrowed. He risks in two ways. He risks ever being able to pay the twenty

thousand dollars, and he risks losing the money he is laying up. It is a wise and safe rule for municipalities as well as for individuals, "If you have a dollar pay your debt with it."

Mr. Codd. I would like to ask the gentleman (Mr. Gilbert), if, when he buys his own bonds, he cancels them?

Mr. Gilbert. I will say that, unfortunately, the men who established our debt issued the bonds, so they are all payable in so many years, and therefore we are compelled to keep them.

Mr. Codd. So each year you have to raise interest on them and pay it to yourselves?

Mr. Gilbert. We clip the coupons and collect the interest ourselves. We know that is not the right way to do, but the bonds are thirty year bonds, all payable in thirty years to the amount of one hundred thousand dollars.

Mr. Hawley. It occurs to me that in issuing bonds the money is used for various purposes. Sometimes it is used for laying pipes or doing work which will last for a long term of years, and again the money is used for pumps, or for some working part, which will wear out in a shorter period of years. And yet it seems to be a rule, at least in this country, to issue bonds for a period of about thirty years, without paying any attention to the purpose for which the money is to be expended, whether it will give returns for thirty years or whether it will give returns for a longer period. I would like to ask Mr. Fuller if he has looked into this matter, and can give us any reason why this period of years is taken, instead of a period of years during which the work for which the money is spent will give a return?

Mr. Fuller. I don't know that I did take into account what the gentleman has suggested. I simply made this tabulation to cover any period from one to thirty years. Of course it could be extended to a good deal longer time by simply adding to the figures. I don't think Mr. Smith answered the question Mr. Beals suggested, with regard to amount he could put in any one bank.

Mr. Smith. I will simply say in reply to that, that the amount we are required to raise for our payments at no time exceeds perhaps twenty thousand dollars. The amount actually deposited in the savings bank I would say would not exceed at any time ten thou-

sand dollars, for the money the last year would be paid towards the debt directly, and it would not be necessary to invest it. I live in a town near a large city where we have access to six or seven different savings banks. All of them are equally good and equally safe, and by depositing a thousand dollars in each bank and allowing it to accumulate to sixteen hundred dollars, we should have in those banks the full amount of ten thousand dollars. The principle I have advocated is precisely the same as has been stated, only the periods are a little longer. If this method of investment is to be followed, it is of course necessary that the amount to be deposited should not be too large. The principle only applies to the smaller towns, where, as I may say it is almost a nuisance to manage a sinking fund.

RESULTS OBTAINED BY THE INTRODUCTION OF THE METER SYSTEM AT ATLANTIC CITY, N. J.

BY W. C. HAWLEY, C. E., ASSOCIATE MEMBER A. S. C. E.

[*Address Sept. 9th, 1897.*]

Atlantic City, N. J., is located on a long, narrow, sandy island, no part of which has an elevation of more than 12 or 15 feet above high tide. Its population ranges from 21,000 in winter to over 175,000 some days in summer. There is no manufacturing, but there are over five hundred hotels and large boarding houses, and about two hundred smaller boarding houses. There is a system of sanitary sewers, the storm water being carried off in the gutters.

In 1882 the Atlantic City Water Co., constructed a system of water works and began to furnish the city with water from the mainland, about six miles distant. From the first there was friction with the city government, and in 1888 the "Consumers" Water Co., constructed a plant and began furnishing water from artesian wells on the island. These two companies consolidated in 1893, and in 1895 both plants were purchased by the city, and have since been operated by a board of commissioners.

During the period of competition between the two companies, waste was encouraged rather than prevented. Many of the cheaper class of houses were on piles or stilts with pipes exposed underneath; and a few days of cold weather would cause an increased pumpage amounting to from 10 per cent to 30 per cent of the normal. Hopper closets were in common use, and the plumbing in a large portion of the less expensive buildings was of the poorest sort. Some meters had been used, but a large bill by meter measurement was frequently the reason for the removal of the meter, instead of the stoppage of the waste. The consolidation of the two companies made little change, as the prospect of purchase by the city was sufficient to defer all improvements.

When, on August 1st, 1895, the city took possession of the works, it was impossible to maintain a pressure of over 20 to 25 pounds during much of the summer season, and the plants were being operated to their limits. The consumption per capita ranged from 200 to over 250 gallons per day. Parts of the city had either no water mains at all, or else those in place were so small as to furnish but little supply. A large amount of pipe was needed in these districts, and when laid, more water would be needed to supply them. The problem confronting the city was either to reduce the enormous waste, or else to provide an additional supply of water, with new pumping plant and mains at a cost of at least $250,000, with the additional cost of operating and maintaining.

Mr. George T. Prince, member of A. S. C. E., who was appointed superintendent when the city purchased the works, recommended the general introduction of water meters and certain extensions of the distributing system. After consulting with Mr. Clemens Herschel, member of A. S. C. E., it was decided to spend $75,000 at once on extensions of the distributing system, and about 16 miles of new mains were laid; also to spend $25,000 in purchasing and setting water meters, the expenditure of $250,000 for a new supply, pumps, force mains, etc., being deferred until the results of the introduction of meters should be known.

The writer was appointed superintendent to succeed Mr. Prince, March 1st, 1896, just as the first of the meters were set. There were at that time about three hundred meters in service (many of them old meters, worn out and practically worthless) on a total of 3,095 taps. On August 1st, 1896, there were 1,916 meters in service on a total of 3,446 taps. August 1st, 1897, there were 2,135 meters in service on a total of 3,692 taps.

The results are shown in the diagrams. Fig. 1 shows the pumpage by months since the works have been operated. Fig. 2 is a comparison of the pumpage profiles for the years 1890–1897 inclusive. It is probable that about 10 per cent of the reduction in pumpage shown is due to improved condition of the pumping machinery and a slightly larger percentage for slip than was formerly allowed. Note should be taken of the fact that on August 1st, 1895, the number of services was 3,095. On August 1st, 1897, the number of services had increased to 3,692, or 19.3 per cent. In spite of this, and almost entirely because of the reduction of waste, the

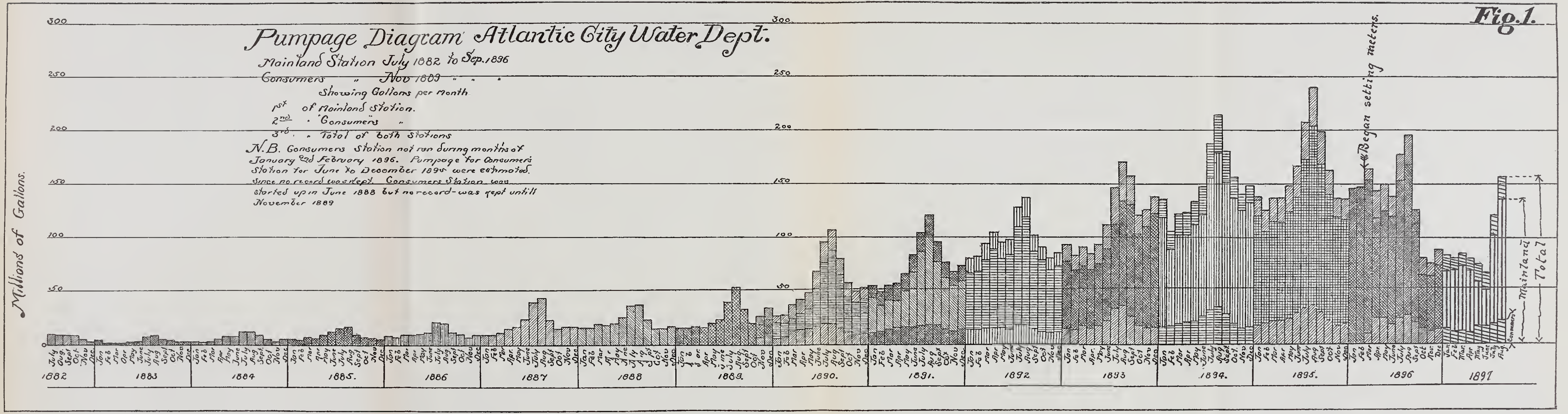


Fig. 1.
Pumpage Diagram Atlantic City Water Dept.
Mainland Station July 1882 to Sep. 1896
Consumers " Nov 1889 " "
Showing Gallons per month
1st of Mainland Station.
2nd " Consumers "
3rd " Total of both Stations
N.B. Consumers Station not run during months of January and February 1896. Pumpage for Consumers Station for June to December 1895 were estimated. Since no record was kept. Consumers Station was started up in June 1888 but no record was kept untill November 1889
Millions of Gallons
300
250
200
150
100
50
Began setting meters.
Mainland
Total
Consumers
1882
1883
1884
1885.
1886
1887
1888
1889.
1890.
1891.
1892.
1893
1894.
1895.
1896
1897

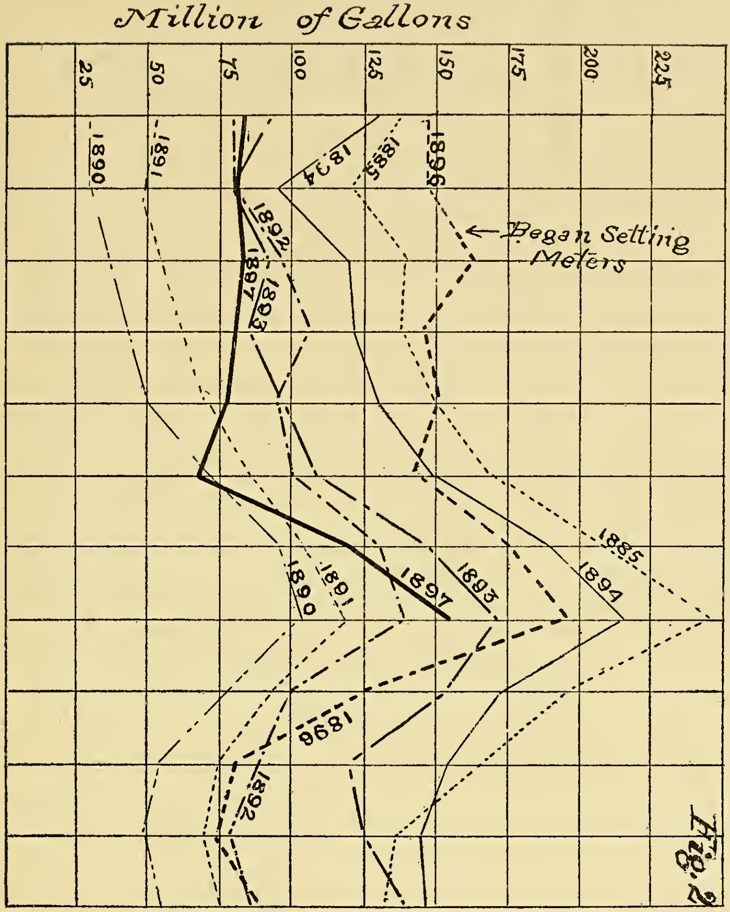


Fig. 2

pumpage shows a very marked reduction. It is true that during this period five of the larger hotels put down artesian wells for their own supplies, but the total reduction in pumpage on this account would not exceed 100,000 gallons per day; and the reduction in pumpage in August, 1897 over that of August, 1895 was 2,700,000 gallons per day. The average number of gallons pumped per tap per day in August, 1895, was 2,500. In August, 1896 this was reduced to 1,775 gallons; and in August, 1897 to 1,350 gallons, or a reduction of 46 per cent from August, 1895. This reduction in

pumpage enabled the ordinary pressure of 35 to 40 pounds to be maintained during the summer months, something which had not been done before in several years and this in spite of the large increase in the pipe system and the consequent additional consumption.

The immediate result of the introduction of meters was to defer for some years the necessity for expending for additional supply the $250,000 contemplated, thus saving the additional interest and sinking fund charges, amounting to at least $16,250 per year. THIS SAVING ALONE IN LESS THAN FOUR (4) YEARS WILL BUY AND SET A METER ON EVERY SERVICE IN THE CITY, and this allows nothing for the saving in extra labor, salaries etc., for operating the enlarged plant.

Fig. 3 shows the diagram of coal consumed at the "Absecon" (or mainland) pumping station since August, 1893. The records of the "Consumers" pumping station are incomplete and can not therefore be included. This shows a decided saving in coal consumed, due as before explained to the reduction in pumpage caused by the meters. Comparing the coal used for the year, August 1st, 1894, to August 1st, 1895, with that used from August 1st, 1896, to August 1st, 1897, there is found an average saving of 2,500 pounds (1.115 gross tons) per day, which at $3 per ton, the cost of the coal in bin, is worth $3.34 per day, or $1,220.93 per year. To this add one-sixth as much to allow for coal consumed at the "Consumers" pumping station, and the total saving is $1,424.41. The interest on the cost of these meters (including cost of setting) is $1,125 per year, so that the saving in fuel alone exceeds the interest on the cost of the meters by $299.41.

It has been shown that the number of taps increased from August 1st, 1895, to August 1st, 1897, 19.3 per cent. Had it not been for the introduction of the meter system it is reasonable to suppose that the additional fuel needed would have been at least an equal percentage, (admitting for the moment that the increased pumpage was within the capacities of the plants, which it was not). This increase would have amounted to $1,244.28 per year, to which add $299.41 (the saving per year already shown in fuel over interest) and the sum—$1,543.69 is more than enough to pay the cost of maintenance and care of the meters—which is about $1,400. This calculation has taken no account of the additional revenue received

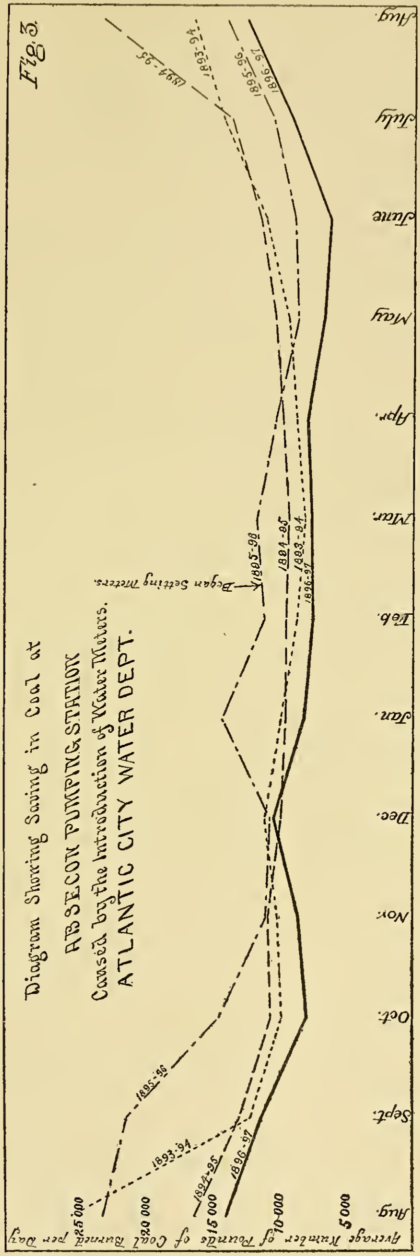


Fig. 3
Diagram Showing Saving in Coal at
ABSECON PUMPING STATION
Caused by the Introduction of Water Meters.
ATLANTIC CITY WATER DEPT.
Began Setting Meters.
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
25 000
20 000
15 000
10 000
5 000
Average Number of Pounds of Coal Burned per Day
1893-94
1894-95
1895-96
1896-97

from the 597 new services, which is easily $10,000 per year. This increase is probably offset however by the decrease in revenue due to the very general saving to the consumers on the meter rate, compared with what they formerly paid on the assessed rate. This reduction of bills has made the meters quite popular, though there is still occasionally heard the wail of some one who did not have repairs made when he should.

It becomes evident therefore, that considered solely as a cold blooded business proposition—not taking into account the equity, justice and other good reasons for its introduction—the meter system in Atlantic City has proved a success. We are now setting 1,000 new meters, and the intention is to ultimately meter every service.

The city council has decided to raise by direct taxation each year a sufficient sum to pay the water department for the water used for fire protection, street sprinkling and other public uses, thus making all property pay directly for these services, in addition to the payment for water actually used on the premises. This allows a lower meter rate than would otherwise be possible—12 cents per thousand gallons. The rates previous to August 1st, 1897, were 18 and 14 cents per thousand gallons.

In connection with this paper, the writer wishes to mention some matters which have come up in connection with the use of meters in Atlantic City which may prove of interest, and which he hopes will call forth some discussion:

First—In introducing meters generally in a city where the assessed rate has been the rule, there is bound to be more or less "kicking" on the part of those who find their bills increased when what is used is measured. This can be largely avoided, and in all fairness and reason should be.

Our meters were as a rule placed on services some weeks previous to the expiration of the term paid for on the assessed rates. Shortly before rendering the bills for the minimum rate in advance, the meters were read, and with a slide rule the number of gallons used per day on the average, for each service, was computed. This was stated on each bill, and if the amount was excessive the consumer was cautioned when he paid the bill. At the end of the first six months it was found that about one-third of the meters had registered in excess of the amounts of the assessed rates formerly paid; one-sixth were practically the same, and one-half were saving money.

Of course there were some protests, and where waste had occurred without the knowledge of the owner, some rebate was given. At the end of the first year it was found that very few still had excessive bills, they had stopped the leaks and waste, and now it is impossible to supply meters fast enough to meet the demand.

SECOND—One of the primary reasons for the introduction of the meter system is to prevent the waste of water. It is therefore desirable to locate the places where the greatest leakage or waste occurs, that such may be the first to be metered, and thus the maximum saving effected with minimum expenditure. A common opinion exists that the greatest waste occurs in the better class of buildings, where fixtures are more numerous; where lawns are sprinkled; where large washings are done; where bath tubs are frequently used, etc. Our experience in Atlantic City does not bear out this theory. We find that one leaky hopper closet (or one that is allowed to run continuously) in some small property that paid perhaps $6 or $8 per year on the assessed rate, will waste water enough to supply half a dozen fine residences, and sprinkle an acre or two of lawns besides —that the stop and waste in a cheap house where it is necessary to shut off the water every cold night to prevent freezing of the pipes, will soon wear and leak, (in this sandy soil) till five or six of them would waste enough water to do the laundry work of the town—that in cheap houses or where there is cheap plumbing, by letting the water run to prevent freezing in cold weather, enough is wasted to furnish baths galore for the whole population. In other words the great bulk of the waste is in the smaller and poorer properties. Of course there are exceptions like manufacturing plants, hotels, saloons with beer pumps, motors, etc., and occasionally we find waste in the better class of houses; but our experience indicates that with a limited amount available for meters, more waste can be stopped in tenements and the cheaper class of dwellings than anywhere else.

THIRD—What tests should be specified for water meters? Our first meters were purchased under the requirement that "no meter shall over-register, and no meter shall under-register more than two (2) per cent."

All meters of $\frac{5}{8}$-inch and $\frac{3}{4}$-inch sizes had to register on a $\frac{1}{32}$-inch stream; 1-inch on a $\frac{1}{16}$-inch stream, and larger sizes on a $\frac{1}{8}$-inch stream. Later specifications have required an average of the larger

streams down to and including the $\frac{1}{8}$-inch to be within the limits of 625 pounds and 630 pounds on a registration of 10 cubic feet, no single test to exceed the limits of + 1 % and — 2 % (618$\frac{3}{4}$ pounds and 637$\frac{1}{2}$ pounds); $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters to test on $\frac{1}{16}$-inch and $\frac{1}{32}$-inch streams within + 1 % and — 5 %; the 1-inch meters to test within the same limits on $\frac{1}{16}$-inch stream; and 1$\frac{1}{2}$-inch meters to test within the same limits on a flow of 1$\frac{1}{2}$ cubic feet per hour. These tests are made under a pressure of 35 to 40 pounds. The testing is expensive, and it has occurred to the writer, that more simple tests might do as well, so far as practical results are concerned. Possibly on the $\frac{5}{8}$-inch, $\frac{3}{4}$-inch and 1-inch sizes a close test on a $\frac{1}{4}$-inch stream, say between the limits of 625 and 630 pounds on 10 cubic feet for accuracy; and a test on a $\frac{1}{32}$-inch stream for $\frac{5}{8}$-inch and $\frac{3}{4}$-inch meters, and on the $\frac{1}{16}$-inch stream for 1-inch meters, with somewhat wider limits, say 618$\frac{3}{4}$ (+ 1 %) and 675 pounds (— 8 %) on 10 cubic feet registration for sensitiveness, would be as satisfactory as a more extended series of tests. The practical value of any test can only be told by observing the operation, in service, of the meters purchased under it.

This matter of testing meters deserves more attention than has been paid to it. A series of standard tests should be adopted and generally used. Varying conditions would have to be met by varied tests; but the conditions in this country are not so diverse but that a series of tests could be arranged which would be practical, satisfactory, and not too expensive.

FOURTH—The meters in use when the city purchased the plants were practically all of the "rotary" type. The first meters purchased by the city were largely of the "disc" type, though all the 1$\frac{1}{2}$-inch, 2-inch and 3-inch meters purchased were rotaries, and a few 1-inch and $\frac{3}{4}$-inch meters. It was found that the smaller rotary meters were more frequently "stuck" than the disc meters. Also that those that had been in service five or ten years were under-registering from 10 per cent to over 90 per cent; and some of them were "stuck" almost every time they were read. Several of the worst of these meters had already been repaired two and three times, at a total expense equal to if not exceeding the cost of a new disc meter. It was found that after being repaired and brought up to correct registration once, the rotary meter gets out of repair much quicker than it did the first time. The department is there-

fore spending very little money on repairs to worn out rotary meters. If simply renewing a worn out part, or some little shop work will put a meter in good condition, it is done. Otherwise it goes into the scrap heap. It is believed that considering the increasing frequency and cost of repairs to rotary meters, and the loss of revenue due to under-registration, it is better policy to replace them with disc meters than to try to keep them in repair. The disc meters cost less, and even if they show equal wear in equal time, which there is no reason to expect, the working parts can be renewed for less than the working parts of rotary meters. The friction for full flow in rotary meters is greater than that in disc meters of the same size, which is an objection where the pressure carried is low, as in Atlantic City. It is also found that the rotary meters are not as sensitive, that is will not register as accurately on the small flows, as the disc meters.

All things considered therefor, it seems best to give preference in the future to the disc type of meter in Atlantic City. Different conditions elsewhere may give different results. It would be interesting to know what results have been obtained in other places. and the writer hopes that the discussion of this paper will bring out the experience and views of others.

STEEL FORGINGS FOR PUMPING ENGINES.

BY H. F. J. PORTER, M. E.

[*Read and Illustrated by Stereopticon, Sept.* 9, 1897.]

So vast is the whole field of engineering that it is beyond the capacity of any one man to cover all of it, and so the profession is subdivided into specialties, one of the most important of which is that of the water works engineer. So comprehensive in itself is this subdivision, necessitating a knowledge of many of the other specialties, that much time and labor must be devoted to keeping up with the progress which is being made in them. If, therefore, some one who devotes his time and attention in one of these contributary directions will present to the water works engineer in a concise form some of the information that the latter would otherwise have to go possibly far out of his way to obtain, the saving in time and labor should come to him acceptably. My excuse, therefore, for drawing on metallurgical engineering for my topic must be that in the multiplicity of your other researches you might not otherwise secure in a handy form for reference the information which I will endeavor to present to you, and which I trust will be of service.

It will not be necessary for me to refer to the constantly growing responsibility which the water works engineer has to assume in designing a municipal pumping-plant. For the money it has invested freely, the public looks to him for a supply of water that never fails for even an hour.

Not only does the safety of property depend upon an efficient fire protection, but many enterprises require an uninterrupted flow of water, and health itself is assured only through the knowledge that cleanliness can be depended upon.

Every detail of your machinery must be of the most approved design and of the best material, lest it fail at a critical moment.

As our cities grow in population demands increase for larger units in our pumping stations, and it is in the nature of large pieces

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NOTE.—A paper similar to the above was presented at the annual meeting of the American Water Works Association held at Denver, Colorado, June 9, 1897.

At the suggestion of several of the members of this Association, Mr. Porter was requested to repeat the paper. The paper as presented is like the original in all respects, except that a few additions have been made to the specifications quoted, bringing it up to date. [Editors.]

of metal, such as are necessary for the component parts of large engines, that, as they increase in size, they are more difficult to make with a certainty that they shall not be defective. The high duty called for in certain localities requires that all parts of such pumping-engines shall be unusually strong.

In such engines, speaking generally, all moving parts and all parts that may be subjected to alternating stresses are made of forgings, and it is to these that I desire to direct your consideration.

In the minds of those who have not given the subject some investigation, a forging is "a forging" simply. The name signifies that the piece has not been cast but has been worked up, somehow or other, under the hammer. Of what it is made, whether of iron or steel, and of what quality of either metal, seems to be of no moment.

That these unconsidered characteristics are, from the changing conditions of the times, becoming of greater and greater importance, I think I can convince you if you will give me your attention while I briefly review the history of the development of the art of forging in this country.

Up to thirty years ago wrought iron was the metal of which nearly everything in the nature of a forging was made. Rolling mills were turning out rails, structural material and merchant bars of wrought iron, and there was plenty of wrought iron scrap of good quality in the market from which forgings could be made. The industrial conditions of the country, however, were such that forges were not called upon to produce forgings of very great size. Those for which a demand was made could readily be built up by welding together small pieces of wrought iron under comparatively light hammers.

About this time, however, the large rolling mills began to change their product from wrought iron to steel, first turning out rails and structural material, later, merchant bars, and subsequently plates. As the manufacturers of the country became more and more familiar with the use of the new material, they began to appreciate that they were getting something that was stronger and more reliable than what they had been accustomed to, and, realizing that they could reduce the sizes of the forged parts of their machinery by using steel, soon began to call for steel forgings. Those that they obtained, however, were far from satisfactory, and with reason, for

the forges had not equipped themselves properly for turning them out. A little explanation may perhaps be necessary.

An iron forging is built up of small pieces and advantage is taken of the property of welding which iron possesses. A steel forging, on the contrary, has to be made from a steel casting larger than the finished piece, as steel does not possess in the same degree the property of welding. It should be, in fact, twice its size in order that the amount of work necessary to make it a forging may enter into the metal during its reduction in size under the hammer. For instance, if you should want a 12-inch shaft, made of iron, it would be built up of small pieces, 4 or 5 inches thick, welded together. If, on the contrary, you should call for a steel shaft of the same size,

Fig. 1.

best practice would require beginning with a piece of steel 24 inches in diameter and forging it down under a hammer the blow of which could be felt through 24 inches of metal instead of only 4 or 5 inches, as in the case of iron; so you can readily see that, when the manufacturers called for steel forgings, the forges did not have the hammer equipment necessary to make them, and there were many other reasons for their inability to supply what was wanted, as you will appreciate when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate to supply, however, so-called "steel forgings," and, although they have never fitted themselves up prop-

erly to this day, they have not hesitated to continue to supply the same thing ever since; but what has been supplied has not been, and cannot be, satisfactory, as I think I will make clear to you as we go further into the subject. The result is that a prejudice has unjustly been established in the trades against steel, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who have been unwilling to spend the necessary amount of money to equip themselves properly for turning out steel forgings.

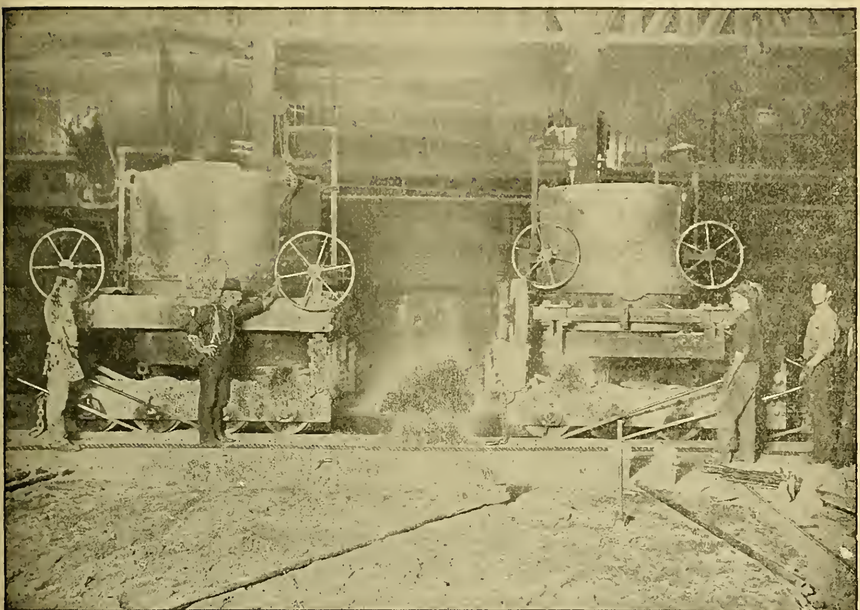

FIG 2.

Since this time, the change from iron to steel in the rolling mills of the country has become almost complete, and today wrought iron scrap is becoming more and more scarce and steel scrap more and more plentiful, so that it is with difficulty that wrought iron forges can prevent pieces of steel scrap from getting into their wrought iron forgings, for there is no way of identifying a piece of steel scrap by sight. When steel gets into a wrought iron forging, it does not weld up with it and causes points of weakness which event-

ually lead to fracture. Fig. 1 shows a wrought iron shaft broken from this cause. The piece of steel can be seen projecting from one piece of the shaft.

Good wrought iron in moderate sized forgings has an elastic limit not higher than 20,000 pounds to the square inch, on account of the large amount of slag and scale which is inherent in the metal owing to its having been puddled, in process of manufacture, in a bath of liquid cinder. Steel, on the contrary, from which the slag has escaped during its melting process, has in its mildest form an elastic limit of about 30,000 pounds, and is therefore at least one-third stronger. For these reasons steel is rapidly driving wrought iron out of the market altogether, and engineers who fully appreciate the situation have already given up the use of iron entirely. Forges are gradually equipping themselves for turning out steel forgings properly, there being one forge in this country which is probably the most complete in the world.

Let me run rapidly through the processes which are considered the best practice for turning out steel forgings.

Fig. 2 shows a small section of a furnace-plant and represents the casting of an ingot. On an elevated shelf are located a series of open-hearth furnaces to which the various ingredients of the charge to be melted are raised on hydraulic lifts. Into these furnaces (which are heated by gas generated extraneously) can be put such a composition of steel as will give the type of forging which is required for the service to which it is to be subjected eventually. Thus from ten (0.10) to fifteen hundreds (0.15) of 1 per cent of carbon make a grade of steel that differs but little in its strength from wrought iron, while an increase in its percentage up to a certain limit tends to make it stronger, and, beyond that, hard and brittle. Too much phosphorus tends to make it brittle when cold, and sulphur to make it so brittle when hot that it cannot be forged properly. Steel of high grade should have not more than .04 of 1 per cent of these elements in it. Others of its chemical constituents affect it in similar and other ways. Their combination in proper proportions can be arrived at only from long experience in constant handling, and by observing their subsequent effect on resultant forgings in actual service. From time to time, during the process of melting, a small dipperful of the molten metal is taken out of the furnace and rapidly tested, to ascertain how the refining is tak-

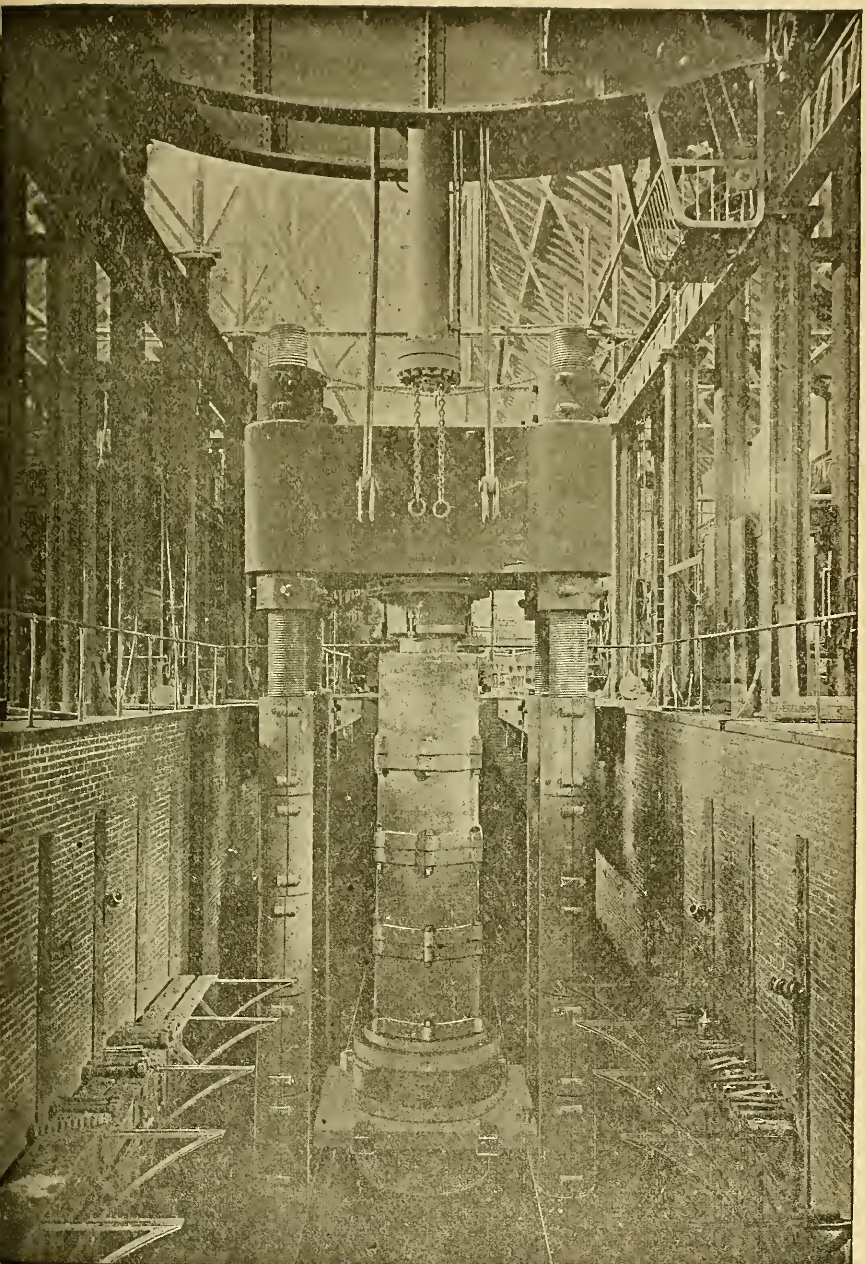

Fig. 3.

ing place, and when the charge is ready the metal is poured from the furnaces into ladles, which in turn empty into moulds located in the casting pit underneath.

Fig. 3 shows an end view of this pit. Here is a mould in which steel is supposed to have been poured from the ladles shown in the previous picture. Moulds of this character are from two to six feet in diameter and are built up in sections to any desired height. In order to make a forging properly, the best practice requires that an ingot be cast about twice its diameter, in order that sufficient work may be put into the original casting during the forging process to give the metal strength and toughness. Besides this increase in diameter a certain amount is added to its length, for reasons which I will try to make apparent to you.

There are various defects which are inherent in steel castings. In the first place, when pouring metal into the mould, air is apt to be entrained and cause blow-holes. In the next place, at certain stages of the cooling process gas is generated and will cause blow-holes of itself. There are several ways of overcoming these defects, but without doubt the most efficient is what is known as the Whitworth process of "fluid compression." In this the mould is placed on a platen and slid underneath an hydraulic press. (Fig. 3.) This press has a capacity of 7,000 tons, and under this enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating.

Another defect, which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the center and the top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and

thus we are enabled to keep the latter filled where otherwise we would have a cavity or "pipe."

Still another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus manganese, silicon, etc.) each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is toward the central and upper portions, where it cools last, thus forming a central core of impurities. This does not occur to such a great extent in small

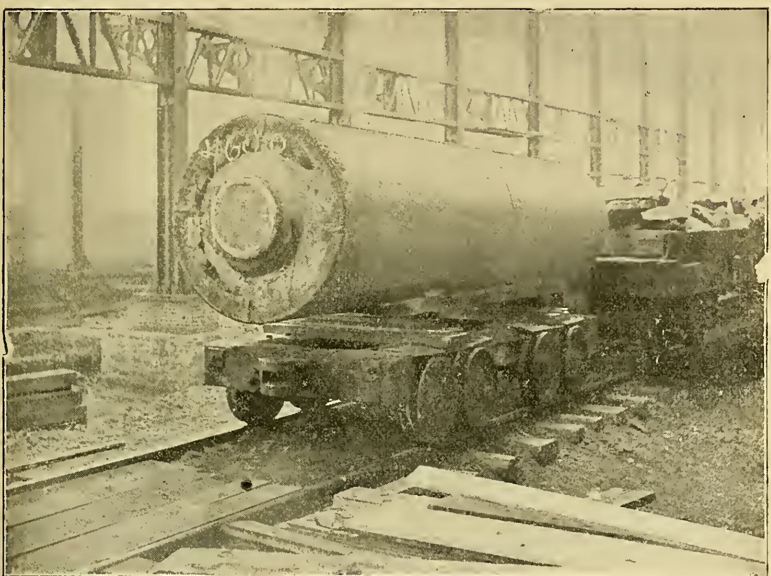

Fig. 4.

ingots, but in all large ingots it does occur, and even this process of fluid compression does not entirely prevent it. But it does succeed in giving us a perfectly solid piece of steel, with the exception of segregation in large ingots, and that defect, I will show later, can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and, if we have any defects in the ingot to start with, they cannot be remedied later by hammering, as might be the case if we were dealing with

iron, which, owing to the slag in its composition, as previously stated, possesses the property of welding.

Fig. 4 shows a fluid compressed steel ingot after being taken from the mould. It is twice the diameter of the forging to be made from it, and has considerable extra metal at its top to take care of piping and segregation, as already mentioned. This extra length, having served its purpose of supplying metal to fill blow-holes and pipes, and of collecting segregation, is cut off and returned to scrap, and the ingot is then ready for the forging process.

The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one, as great care must be taken to make the heat penetrate the metal slowly and uniformly.

As I have already told you, the metal in the ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain

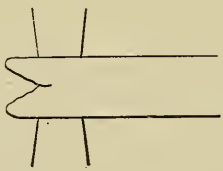

Fig. 5.

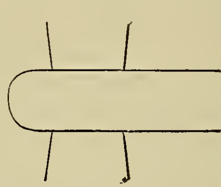

Fig. 6.

throughout its interior. Now, if we put a cold ingot into a furnace to be reheated, we immediately expand the surface metal and pull it still further from the center, thus putting an additional strain on the metal inside. In very large ingots cracks are thus apt to be started in the center, and forgings are very liable to break in subsequent service from the fact that they have not been properly reheated. This process is not considered of sufficient importance by forges generally, and a great many forgings fail from lack of care being taken at this time.

Now comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be of sufficient power and of such a character as to penetrate to the center and cause flowing throughout the mass. This flowing of the metal requires a certain amount of time, and the requisite pressure should be maintained throughout a corresponding period.

Fig. 5 shows the effect of forging a large shaft under a light hammer. The blow is made very quickly, forced by top steam, so that the metal has not sufficient time to flow and all that has been accomplished is damage to the surface metal without any effect whatever being produced on the center. There is a tendency to draw the surface metal away from the center, and on all large shafts which have been forged under light hammers will be found

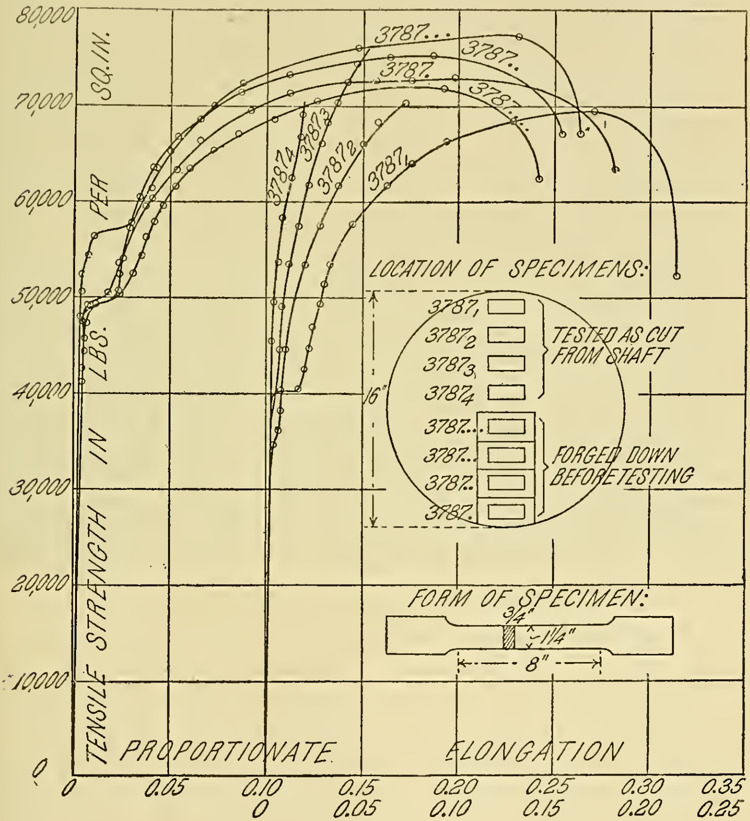

FIG. 7.

that well known concave end which is shown in the sketch, where the surface metal has been drawn away to such an extent as to leave cracks and sometimes large cavities in the center. What is shown at the end is simply an evidence of what has occurred all the way

through the shaft. Now, if we use a press in place of a hammer on a shaft of the same size, the pressure is applied very slowly, allowing time for the molecules of the metal to flow easily, and we then have the pressure passing all the way through the metal, and, as the center is hotter than the surface, and therefore softer, it will be squeezed out, and you will have the convex shape shown in Fig. 6 on the end of the shafts that have been hydraulically forged. By the press only can large shafts be obtained without defects formed during the process of forging.

Many so-called "steel forgings" are, even at the present day, turned out by forges which have not sufficient capacity to make them properly. Instead of working them down from ingots twice their diameter, as best practice dictates, they are compelled, because they have not hammers heavy enough to do the work, to use ingots which are only slightly in excess of the size of the finished forging. Such forgings are little better than steel castings and do not last long in service, and even when an ingot of proper size is insisted upon the surface metal only is affected, the center remaining in its original condition.

Fig. 7 is a diagram by Prof. Johnson, of St. Louis, showing a series of tests made at the Watertown Arsenal by the Government on a 16-inch shaft. This shaft was made for the United States cruiser "Dolphin" under a 10-ton hammer from a 30-inch steel ingot—which was very nearly the proper size—but broke after being in service a short time. In order to find out the cause of the break, test specimens were taken out of the metal at various distances between the surface and the center, specimens 3787 $_1$—$_2$—$_3$ and $_4$ being taken first. Their form is given, and the tests are graphically shown in the curves. The test piece 3787_1, nearest the surface, showed an elongation of 21.4 per cent, and a contraction of 32.8 per cent; 3787_2 showed an elongation of 7.2 per cent and a contraction of of 5.5 per cent; 3787_3 showed an elongation of 4.9 (practically 5) per cent and a contraction of 5.2 per cent; and the one nearest the center showed an elongation of 2 per cent and a contraction of 1 per cent. In other words, the elongation varied, between the surface and the center, from 21.5 per cent to 2 per cent, and the contraction varied from 33 per cent to 1 per cent. You can see, therefore, that the center metal in this forging was practically unworked. In order to be certain that there was nothing in

the metal itself that would give this difference, they cut out from the opposite side specimens of a larger size and forged them down until they were of the same size as the first, or, to state it differently, they put work into the metal that ought to have been put into it when it was first forged, and, as a result, an average of 25 per cent elongation and 55 per cent contraction was obtained.

Fig. 8.

Fig. 8 represents the same ingot shown in Fig. 4, now being drawn out in the forging process. In this process of reduction in diameter and increase in length a great deal of work has been put into the metal. In order that the metal should be worked at the proper temperature, it is necessary to re-heat it a number of times, and every time a blow is made by the press the metal has been worked under conditions differing from those existing when the preceding blow was made, because it has cooled a little in the interval. As, therefore, no two parts of the forging when finished have been treated the same, it is natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been re-heated from time to time in different

parts, as the forging process passes from one end of the piece to the other. To relieve these various strains all forgings are subjected to a final process called "annealing." This consists in put-

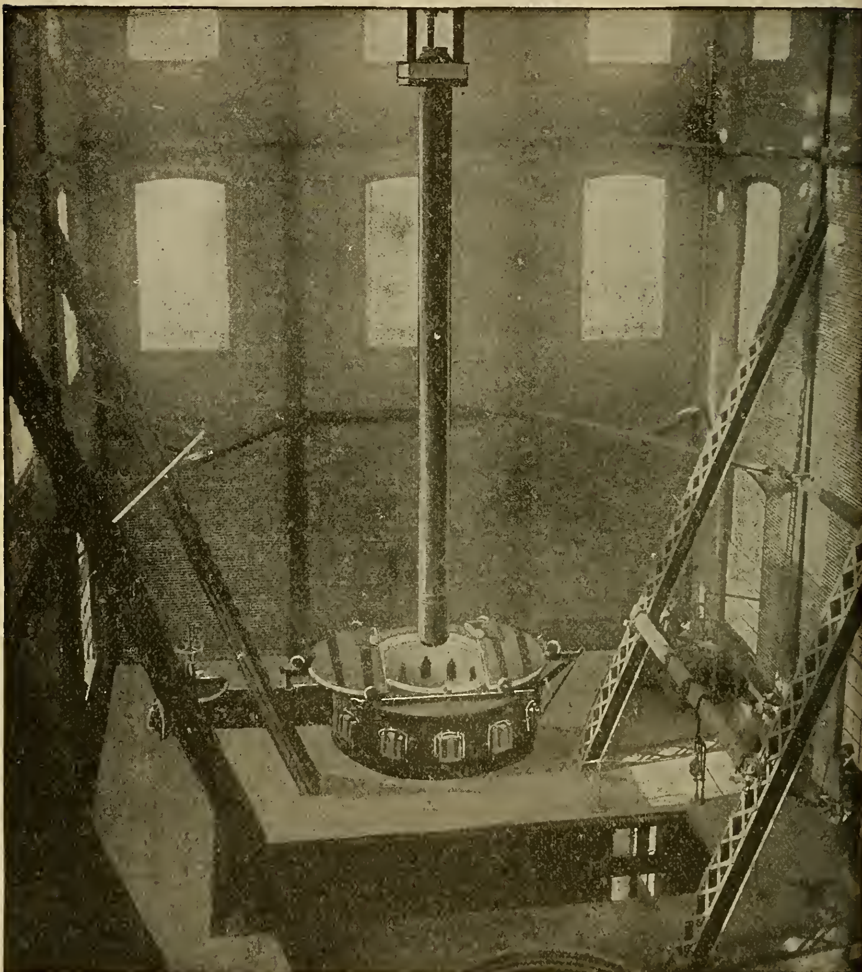

Fig. 9.

ting the forging into a furnace, starting a wood fire around it, and heating it to a definite temperature which experience teaches is best suited to the service to which the forging will eventually be

put; the fire is then allowed to die out and the furnace and forging to cool down slowly together. An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased considerably, as shown by its contraction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods, which is from two to ten thousand pounds lower.

All forgings should be annealed, and all specifications should be drawn so as to require that treatment. It is a process which is very seldom practiced in forges because not often required in specifications, and no one can tell whether a forging is annealed or not until after it has been in service for some time, when the cooling and forging strains develop and throw the piece out of shape.

In order to obtain from steel the very highest results there are still other processes to which it should be subjected after forging so as to develop its physical properties. One of these is that of "tempering."

Fig. 9 shows a tempering-plant. The forging is first re-heated to a definite temperature in a vertical gas furnace, then taken out and lowered suddenly into a bath of cold liquid, which may be oil or any other suitable fluid. The shaft in the picture is shown hanging from a traveling crane after having been withdrawn from the furnace, and is about to be lowered into the cold bath shown in the foreground. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition existing after forging is broken up, and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionately to the tensile strength, and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces.

In order to successfully temper a piece of steel, great care must be taken both in the process of re-heating it and also in cooling it in

the bath. During re-heating the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained ; and in dropping it into the cold bath the surface metal is apt to contract on to the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging it should be hollow. By taking out the centre, the piece can be re-heated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and the exterior together. Again, when immersing it in the cold bath, there being no solid center on which the surface metal is contracted, the danger of cracking the surface during the cooling process is in that way eliminated.

There are two ways of making a forging hollow. The ordinary way of getting rid of the center is simply to bore it out. After boring the forging is tempered, and thus the strength lost with the metal taken from the center is restored.

The hollow shafts which were first introduced into this country by Fried. Krupp of Germany have all been forged solid, bored, and oil-tempered. The high grade of that kind of work is well known.

Another way of getting rid of the center of large forgings is to *forge them hollow*. Any one who has not considered the subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already explained to you that there are various defects which occur in ingots, the most serious of which are segregation and piping, and that it is in the center and upper portion where those defects occur. Now, if we were to cast a hollow ingot, replacing the center metal by a solid core of fire-brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and would transfer the position of last cooling to an annular ring midway between these surfaces, where we would collect the piping and segregation. This would not do, because the metal there is what we are going to depend upon for the strength of our hollow forging, and we are therefore compelled to make our forging solid, as before, so as to collect the piping and segregation in the center and at the top, where we have added metal to the original ingot for the purpose.

Then, having cut off the top and thus gotten rid of what piping and segregation are there, we bore out the center, and so eliminate the piping and segregation at that point, what we have left being as

sound and homogeneous a piece of steel as can be obtained (Fig. 10.)

After the hole has been bored, the next step is to reheat the ingot, and, since the center is taken out, as before explained, this process is not as delicate a one as if the ingot were solid. The heat affects the interior equally with the exterior and the two expand together, thus avoiding the danger of cracking. When the ingot is reheated we put a steel mandrel through its hollow centre, and, subjecting the two to hydraulic pressure, force the metal down and out over

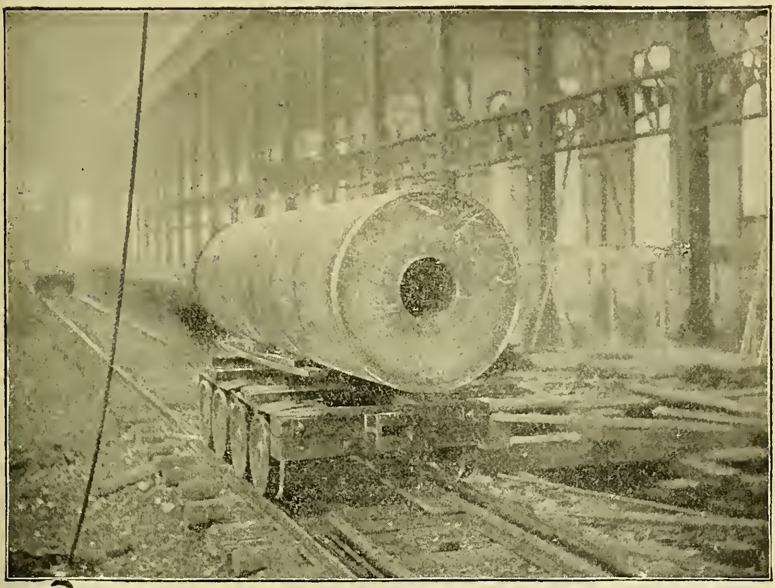

Fig. 10.

the mandrel (Fig 11). We thus practically insert into the forging an internal anvil and have therefore actually much less than one-half the amount of metal to work on that we would have had if the piece were solid. We have, for instance, in Fig. 12, a shaft 32 inches outside diameter with a 16-inch hole through it, leaving only 8 inches of metal to be worked upon between the press and the internal anvil.

A large number of hollow shafts of this type have been made for pumping engines in municipal and mining plants throughout the country, and similar shafts have also been made for engines in street

and elevated railway power-plants. These shafts have been about 28 inches outside diameter, 11 inches inside diameter, and twenty-five feet long. The Government requires that shafts for the navy shall be hollow, and this custom is being rapidly taken up in general marine practice.

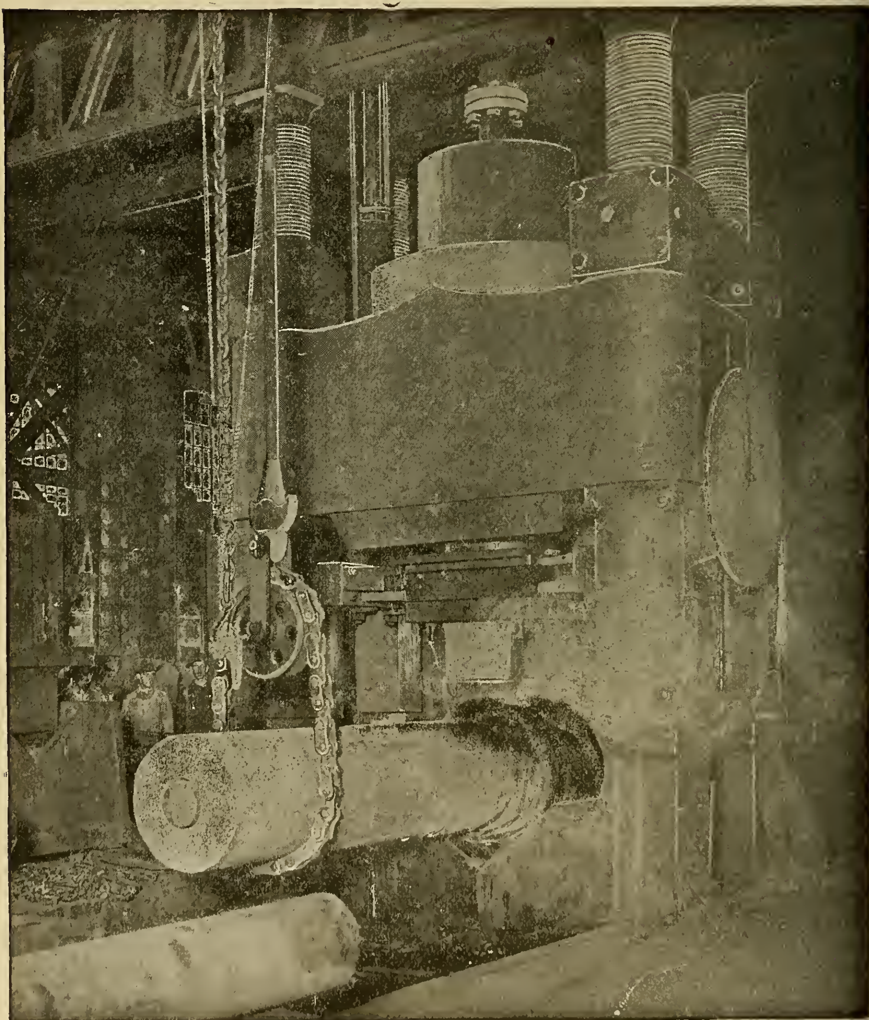

FIG. 11.

With the substitution in the trades of steel for wrought iron for engine and miscellaneous forgings, the tendency at first was to use a very mild, soft steel, approaching wrought iron in the ease with which it could be handled in the shop, especially in machining.

Mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity and freedom from danger of imperfect welds and porous spots enclosing slag, etc. Still it does not possess the very desirable quality of high elastic strength, combined with ductility or toughness, in as great a degree as can be obtained

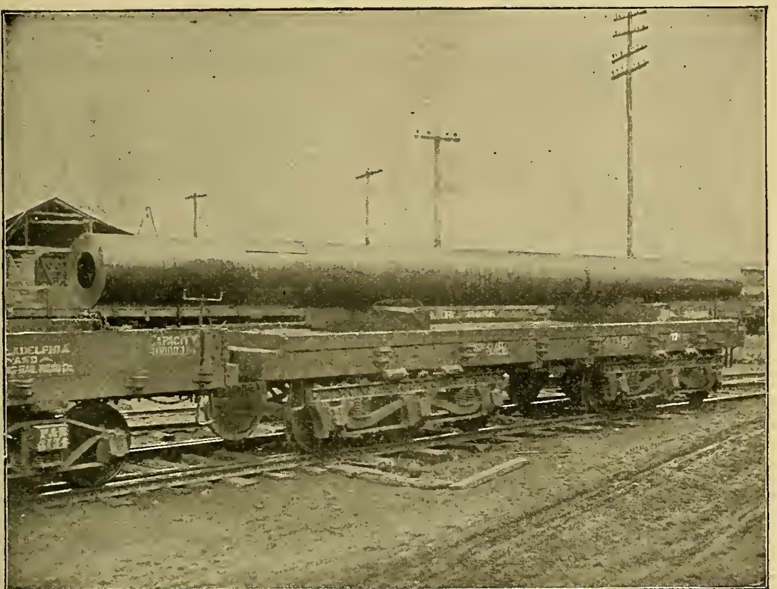

FIG. 12.

without danger in a harder steel, when proper precautions are taken in its manufacture.

It is only in recent years that high carbon steel has been found available for forging work. Fried. Krupp of Essen, Germany, was the leader in substituting his soft crucible steel for wrought iron, in heavy forgings. After 1870, soft open hearth steel became a more frequent substitute, with such success that, compared with wrought iron, the soft steel forgings made by well known English manufacturers soon attained a high reputation for their quality. It

was therefore natural that our government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the direction of the English practice, and called for a steel having a tensile strength of about 65,000 pounds per square inch, and a minimum elongation of about 28 per cent in four diameters. Today, however, we are called upon by our government to furnish a steel for the above purposes which will show a tensile strength of 80,000 pounds per square inch, an elastic limit of 50,000 pounds, and an average elongation of 25 per cent in four diameters.

The character of steel now used for crank-pins by many railroads furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins, in place of wrought iron, a soft, low carbon steel was generally employed, and the failures due to "fatigue of metal" were almost as numerous as when wrought iron was used. The broken pins showed what has been called a "fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 to 50,000 pounds per square inch, failures were greatly diminished without changing the diameter or shape of the pins.

"Fatigue tests" are made at the Watertown Arsenal by rotating rapidly a bar weighted in the center sufficiently to place the extreme fibres of the metal alternately in extension and compression.

These show the relative strength of steels of varying carbon to be about as follows:

.24 per cent carbon steel,		annealed	229,300	rev.
.24	"	oil-tempered	348,000	"
.46	"	annealed	976,600	"
.46	"	oil-tempered	1,657,500	"
.66	"	annealed	3,689,000	"
.66	"	oil-tempered	4,223,600	"

The elastic limit, not the ultimate strength, is the proper point on which calculations should be made. This is the point which should not be exceeded at any time by the stresses which may be imposed upon metal. It is a point, however, very difficult to obtain

in ordinary practice, and requires delicate and special apparatus for its determination. It is usually considered to be the same as the "yield point" shown by the drop of the beam of the ordinary testing machine, but, when so determined, may be from 2,000 to 10,000 pounds too high.

This high carbon steel has been used largely by such representative pumping-engine builders as The Edward P. Allis Co., Fraser & Chalmers, H. R. Worthington, The Southwark Foundry & Machine Co.,The Lake Erie Engineering Co., Holly Mfg. Co., E. D. Leavitt and others. In general it can be stated that experience now shows that, where high duty is demanded of a forging, mild steel of a tensile strength of 60,000 pounds is not the best material to use, owing to its low elastic limit. The tendency is now toward the adoption of a higher carbon steel, followed by such treatment as will raise the elastic limit relatively to the ultimate strength.

Engine builders, although fully alive to the advantages of the use of high carbon steel, are deterred from its use by the fact that it is very tough, and therefore the cost of machining in the shops is high. In competition with his fellows the engine builder who uses the lower carbon steel can bid lower than he who uses the better grade. It is therefore to the interest of the water works engineer, who specifies what he wants, to insist upon his specifications being worded properly, so that all the bidders can base their calculations on the same grade of material.

The water works engineer does not want his engines composed of a weak and unreliable material merely because the engine builder finds it easier and cheaper to manipulate in shaping. He should follow the progress in steel making and insist upon getting the best he can afford to buy. The first cost may be a little greater, but he will save by getting a material much stronger and stiffer, and which will receive a higher polish. The lessening of friction of such parts alone will pay the difference in cost by the saving in fuel and lubrication.

Experience must teach the engineer what quality of steel is best suited for the various parts of his engines, and his judgment must determine whether he will use a high quality and decrease the size of his forgings, or a cheaper grade, putting in more metal and taking greater risk.

Although forgings can be made to fill a large variety of specifications, they can in general be divided into six classes, as follows:

1st,	mild steel, annealed.	
2nd,	medium hard steel, annealed.	
3rd,	" "	oil-tempered.
4th,	nickel steel, annealed.	
5th,	" "	oil-tempered No. 1.
6th,	" "	" No. 2.

Each of these classes is supposed to cover a series of grades of steel, varying in strength by several thousand pounds. In selecting the material for the forgings of an engine, and in drawing up the specifications therefor, the premise should not be omitted that "all forgings shall be made of open hearth steel," and that "they shall be carefully annealed after forging."

Large shafts and similar forgings, crank and cross-head pins, should be made of fluid compressed steel, and should be hydraulically forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to insure absence of any internal defects. If shafts are oil-tempered, the hole can be made larger in diameter than if they are simply annealed, and where the hole is 7 inches in diameter and above, shafts can be forged hollow on a mandrel. A hollow-forged, oil-tempered shaft insures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired.

Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and subsequent heat treatment has been completed. Such prolongations should receive no greater reduction than the forging at its largest part.

The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring-points, $\frac{1}{2}$-inch in diameter, and cut from full size prolongations of the forgings after treatment; the elastic limit being determined not by the drop of the beam but by an electric micrometer.

Simple steel.	Tensile strength.	Elastic limit.	Extension percentage.	Contraction percentage.
1st, annealed,	58,000	28,000	28	55
2nd, "	80,000	37,000	23	45
3rd, oil-tempered, with axial hole,	80,000	45,000	25	50
Nickel Steel.				
4th, annealed,	80,000	45,000	23	45
5th, oil-tempered, with axial hole,	80,000	50,000	25	50
6th, oil-tempered, with axial hole,	90,000	60,000	22	50

Here are extracts from a few pump specifications picked up at random, from which it will be seen that they differ radically, although for about the same type of engine.

St. Louis Pumping-Engines. 1896.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Company, Bethlehem, Pa., and have a tensile strength of not less than 75,000 pounds per square inch of section, and show an elongation of 20 per cent in four diameters. Specimens to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be properly annealed."

Chicago Pumping-Engines. 1896.

"All steel forgings used in shafts and crossheads shall have a tensile strength of not less than 65,000 pounds per square inch, and show an elongation of 25 per cent in 2 inches, and for connecting-rods a tensile strength of not less than 58,000 pounds per square inch, with an elongation of 28 per cent in 2 inches. Crank-pins shall have a tensile strength of not less than 75,000 pounds per square inch, with an elongation of 20 per cent in 2 inches. Specimens to be taken from full sized forged prolongations after annealing. All forgings shall be thoroughly annealed."

Boston Pumping-Engines. 1896.

"The crank-shaft and crank pins shall be of the best quality of forged fluid compressed steel.

"Steel forgings shall have a tensile strength of not less than 60,000 pounds per square inch of section, and show an elongation of not less than 20 per cent in 8 diameters. No steel shall be welded."

New Bedford Pumping-Engines. 1897.

"All forgings are to be of crucible or nickel steel; each piece to be oil-tempered. All steel is to have at least 50,000 pounds elastic limit per square inch, and 18 per cent elongation in 10 inches in test pieces 1 inch in diameter. Where forgings are shown to be bored out they may, if preferred by the contractor, be hollow forged instead of bored."

Buffalo Pumping-Engines. 1897.

Specifications read same as for the St. Louis pumping-engines above mentioned, and, in addition:

"The steel shall not contain more than .04 of 1 per cent of either sulphur or phosphorus, and not less than .40 of 1 per cent carbon."

Boston Pumping-Engines. 1897.

"The crank-shafts, cranks and crank pins, the piston, connecting, and plunger-rods, the crossheads and crosshead pins shall be made of fluid compressed or crucible steel of substantial proportions. Test pieces for forgings shall be cut from full size prolongations of forgings and shall receive the same treatment as forgings. Steel forgings for crank-shafts, cranks, crank-pins, crossheads, crosshead-pins, plunger, connecting, and piston-rods shall have an elastic limit of not less than 50,000 pounds per square inch and an elongation of not less than 18 per cent in 10 inches in a test piece 1 inch in diameter. Steel forgings shall be made without welds."

Chicago Pumping-Engines. 1897.

"All steel forgings used in the construction shall be equal to forgings manufactured by The Bethlehem Iron Co., Bethlehem, Pa., and have a tensile strength of not less than 65,000 pounds per square inch of section and show an elongation of 20 per cent in four diameters. Test specimens are to be taken from full sized forged prolongations after annealing. Shafts and crank-pins shall be hydraulic forged, fluid compressed steel. All steel forgings shall be thoroughly annealed."

Cincinnati Pumping-Engines. 1897.

"All steel must be of open hearth make, and shall contain not more than .05 of one per cent of phosphorus and not more than .03 of one per cent of sulphur. It shall be tough, ductile, of uniform texture and composition, and shall show a fracture of fine silky grain.

"Different grades of steel when tested in specimens of $\frac{1}{2}$ square inch in sectional area, cut out of the finished piece, shall give the following results:

"Tensile stress without breaking, not less than 70,000 and not more than 80,000 pounds.

"Elongation in twelve diameters 20 per cent.

"Cold bending of specimen 180 degrees and setting flat on itself without sign of fracture.

"All steel forgings shall be hydraulic forged and properly annealed."

Pumps for Pope Manufacturing Company. 1895.

"The shafts are to be of fluid compressed open hearth steel, oil-tempered when built up, and properly annealed when not built up, having an elastic limit of 45,000 pounds, and 18 per cent elongation in 10 inches, in a test piece of 1 inch diameter."

It has been customary in the past for cities to have water supplied at moderate pressure throughout their systems of mains, and, in case of fire, etc., special engines take their supply at hydrants in the immediate locality of the fire. Owing, however, to the great drain on the mains at certain hours of the day, some cities have laid special systems of fire-mains through their streets leading to some accessible water front, patrolling which are fire-boats equipped with powerful pumping-engines. These engines supply water to the special mains at very high pressure.

These boats must be of light draft, and, necessarily, the pumps must be very light and strong, and the highest grade of steel must be used in their construction.

Centrifugal pumps, turbines and similar apparatus, which work on either solid or hollow shafts, should be supplied with a grade of steel suited to their requirements.

The power plant at Niagara, which comes in the above category, has specified for it steel having an elastic limit of 55,000 pounds, elongation of 23 per cent and contraction of area 50 per cent. Fig. 13 shows a specimen forging made for that plant.

I trust that I have been able to gather together for the members of this Association a few suggestions regarding forgings which may result in a saving of time and labor in searching for such information elsewhere.

I have endeavored to point out the direction in which improvement in forging processes is tending, and to offer suggestions by which the various grades of steel forgings can be obtained. If I

have succeeded in satisfying you that the day of wrought iron forgings has passed, and that the use of mild steel forgings is rapidly giving way to steel of higher carbon, I will feel that I have accomplished what I started out to perform.

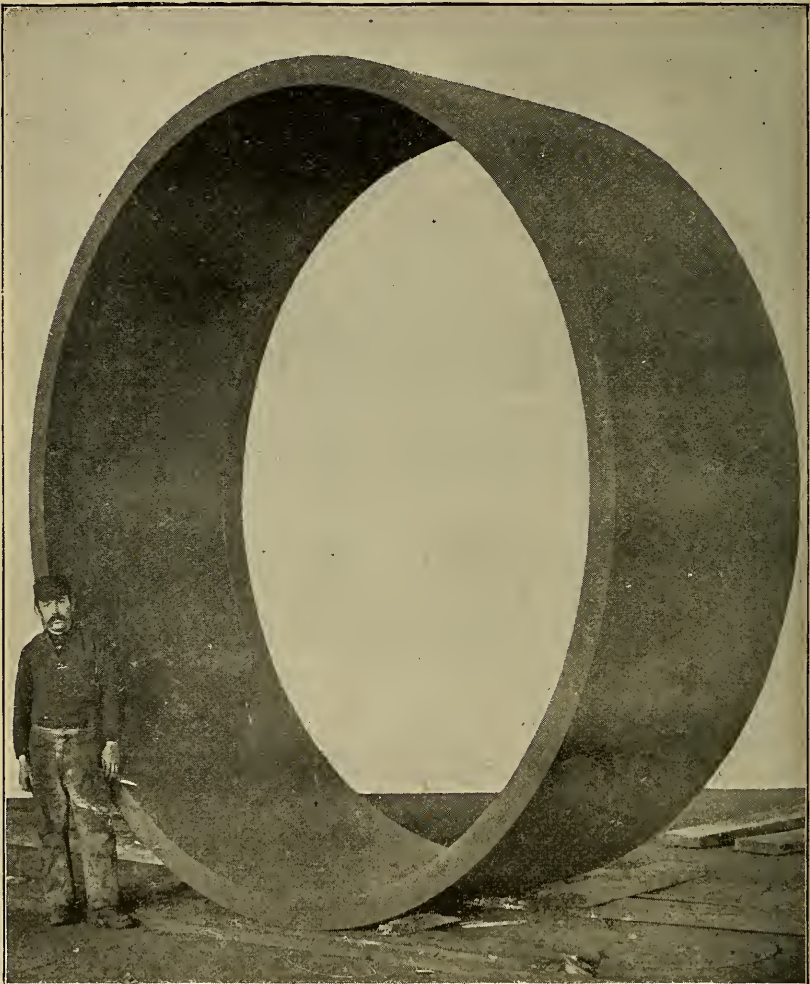

FIG. 13,—Field ring for one of the 5000 H. P. Electric Generators at Niagara Falls. Outside Dia., 11 ft. $7\frac{3}{8}$ in ; width, 4 ft. $\frac{3}{4}$ in.; thickness, $5\frac{1}{4}$ in.

NOTE.—Papers on this and analogous subjects have appeared in the Transactions of the Society of Naval Architects and Marine Engineers, Vol. I, 1893, by R. W. Davenport, and in Proceedings of the Engineers' Club of Philadelphia, Vol. XIII, No. 4, by A. L. Colby ; also in Vol. XVII of the Transactions of the American Society of Mechanical Engineers by H. F. J. Porter.

NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

CONSTRUCTION OF THE NEWPORT, N. H., WATER WORKS.

BY LUCIAN A. TAYLOR, C. E., BOSTON, MASS.

[*Read Dec. 8, 1897.*]

Newport, N. H., is on the Concord & Claremont branch of the B. & M. Railroad, a few miles west of lake Sunapee. The great game preserve of the late Austin Corbin lies partly in the town.

The village contains a population of about 1,500 people, and is beautifully located in the valley of Sugar river, the outlet of lake Sunapee.

The water works were built in 1894.

Water was taken from Gilman's pond in East Unity, about six miles southwest from the village. This is a natural pond of very pure water, the shores being very clean and free from vegetable growth, and composed of sand and gravel. It has an area of 65¾ acres, and is said to have a depth of from 40 to 50 feet.

A dam was built at the outlet of the pond to replace a small one that had been used by mill owners on the stream below. The exact area of the water shed is not known but is believed to be about one square mile. The dam is 8 feet wide on top with inner and outer slopes 2 to 1. The greatest height is about 14 feet, length 126 feet, wasteway partly over natural rock, 34 feet in length. The inner slope is paved with field stone. A core wall 3½ feet thick at the bottom, 2 feet thick at the top, extends to within 1½ feet of the top of

the dam. Its greatest height is about 13 feet. It is laid in Rosendale cement mortar, the stones being ordinary field cobbles of rather small size, no stone allowed to lay more than two-thirds the width of the wall.

A 12-inch waste pipe extends through the base of the dam to a gate chamber 66 feet from the top slope of the embankment. The supply is through an 8-inch pipe laid parallel with the waste pipe, and terminating in the gate chamber.

The gate chamber is 10 feet square at the base and 8 feet square at the top outside. The walls are 3 feet thick at the bottom, and 2 feet at the top, laid of rubble masonry in Portland cement mortar, and are 12 feet high. The foundation is 3 feet thick, of rubble masonry, laid in Portland cement mortar.

A brick gate house was built over the gate chamber in which are the gate rods. On the up stream face of the gate chamber, there is an opening 2 feet in width extending from the top of the foundation to the floor of the gate house. On the sides of this opening are grooves formed by placing angle irons in the masonry. These are to hold the stop plank and screens.

The foot-bridge connecting the gate house with the dam is in two spans, each about 33 feet in length, supported at their connection by two cast iron columns made of 8-inch cast iron water pipe filled with cement concrete, and built into stone foundations in the bottom of the pond. The depth of water in the gate chamber is 8.4 feet, and the amount of water above that level is 166,000,000 gallons. Practically about 150,000,000 gallons can be drawn.

The elevation of Gilman's pond is about 480 feet above the lowest point of the village. The supply is through 1435 feet of 8-inch, and 23,771 feet of 6-inch pipe laid across private lands, and along the highway, to a reservoir about one mile from the centre of the village.

There are numerous abrupt summits along this pipe line. Eight or nine stops for air valves were placed along the line. They are made of ¾-inch stop and waste and ¾-inch upright pipes. A box is placed over each stop. After the first filling of the pipe line, these stops are rarely if ever used, even when a considerable portion of the water has been drawn off.

The elevation of the reservoir is 169 feet below Gilman's pond. The capacity of the pipe line is about 400,000 gallons per 24 hours.

The reservoir is built upon a steep side hill, the average slope of which is about 21 feet per 100. The capacity of the reservoir is 701,-300 gallons. The embankment on the lower side is 13 feet in width on top. The inner slope is 1½ to 1. The outer slope, about 2 to 1. The depth of water is 12 feet. The bottom of the reservoir and inner slope are paved with ledge stone 12 inches in thickness. The top of the embankment is 4 feet above high water in the reservoir. The reservoir at high water mark is 104.5 feet x 116 feet.

Three lines of pipe pass through the westerly or lower embankment; one is an 8-inch waste pipe, passing through the gate chamber and terminating just outside the wall. In the gate chamber there is an upright pipe acting as an overflow from the reservoir. The supply pipe from Gilman's pond 8 inches in diameter at this point, passes through the gate chamber to the centre of the reservoir, terminating in a quarter turn. The distribution main for the village, 12 inches in diameter, passes through the gate chamber, also terminating about 12 feet from the outside walls. Over the end of this pipe is a copper wire screen, 14 inches in diameter and about 15 inches in length.

At the upper or southeast corner of the reservoir, there is a wasteway over the natural ground placed at the same elevation as the overflow pipes in the gate chamber.

As the reservoir was made somewhat larger than at first contemplated, the additional excavation required, uncovered a portion of ledge in the northeast corner and also over a considerable portion of the bottom of the reservoir. In excavating this ledge which for the most part was smooth, solid granite, it was discovered there were holes and fissures of considerable depth and extent, extending across the bottom of the reservoir, and at the northwest corner, underneath the embankment already built. These crevices were followed, uncovered, and exposed, as far as possible, the loose fragments of rock in the crevices being taken out as far as practicable. The holes were then filled with pure cement grout, and allowed to set for several days. The surface was then covered with from 18 inches to 3 feet in depth of well rammed and puddled material from the excavation of the easterly slope of the reservoir. This material was of excellent quality, having sufficient amount of clay to make it water-tight. The reservoir embankment is entirely of material from the excavation, no masonry or core wall being used in

its construction. Trenches were excavated in the natural ground 3½ feet in width, and 3½ feet in depth into the impervious material, and filled with puddle from the excavation. They extended the entire length of the lower or westerly embankment, and somewhat more than past the centre of the reservoir on the northerly and southerly ends. Masonry was placed around the inlet pipes through the embankment to the gate chamber. There are also several cut-off walls extending below, above and upon each side of the pipe wall.

It may be of some interest to note the result of this method of dealing with the fissures uncovered in the rock excavation. The reservoir has now been in use three years, and is in a perfectly good condition. There was some percolation when the reservoir was first filled, mainly showing itself in the increased flow of a spring about 200 feet distant from the southwest corner of the reservoir. This flow has considerably decreased since the reservoir has been in use. The amount of actual percolation from the reservoir itself is difficult to estimate, as the spring was a very constant and powerful one during the entire construction of the work. It is probable the percolation amounts to from 15,000 to 20,000 gallons in 24 hours.

In the northwest corner of the reservoir a considerable portion of the rock is left exposed, forming the inner slope of the basin. The writer has no doubt that most of the percolation finds its way through minute crevices and seams in this rock, and not through the bottom or lower embankment where the cement grout and puddle had been placed in and over the crevices.

There were used 56 barrels of cement in filling these holes, which extended in some cases, 20 or 30 feet in length, and from 1 to 12 inches in width. These fissures were, no doubt, occasioned by the movement down hill of the entire slope which rises several hundred feet above the location of the reservoir. These holes and crevices also account for the large and constant flow of the spring, which during time of construction supplied at all times an abundance of water for use in the construction of the embankment and masonry, and also for the men and teams employed upon the work.

It is not probable that any movement of the slope of the hill is taking place at the present time, or is likely to take place in the future, although such things do occur frequently in granite and other quarries in New England.

The distribution system is through 976 feet of 12-inch, 4826 feet of 10-inch, 4985 feet of 8-inch, 16,583 feet of 6-inch and 1926 feet of 4-inch pipe, a total of 29,296 feet, or 5.55 miles, upon which are placed 50 hydrants and 49 gates.

The pressure upon the mains ranges from 90 to 134 lbs. per sq. inch. Near the foot of the hill below the reservoir, and at the lower end of the 12-inch pipe, there is a connection with the supply pipe from Gilman's pond, so the village may be supplied without the water passing through the reservoir. The entire length of the pipe line as laid is 55,075 feet or 10.43 miles.

Work was begun on this system June 11, and completed Nov. 15th, 1894, since which time the works have been in constant and regular use.

At a test of the system when the reservoir was partly filled with water, 9 fire streams were used with a reduction of about 20 lbs. in pressure upon the street mains.

More streams were not used for lack of hose and nozzles. About one year ago a connection was made with a large woolen mill and upon a test, 11 good fire streams were thrown from the dead end of an eight inch main, about 1½ miles from the reservoir.

DISCUSSION.

MR. HASKELL. I would like to ask Mr. Taylor if the character of the water has been good ever since they commenced using it?

MR TAYLOR. It has been uniformly good. The dam I spoke of did not raise the water above its natural flow line. There had been a dam built by mill owners so that they might draw 7 or 8 feet, but that was mostly of natural soil, and I simply replaced the old structure with something more substantial, but without raising the water above its natural level; it simply enabled us to draw 8 feet off from the natural elevation.

MR. FULLER. I didn't exactly understand Mr. Taylor when he spoke about this "movement," whether it was before the reservoir was constructed?

MR. TAYLOR. I suppose that was in prehistoric times; a geological movement. I have seen in granite quarries those movements, which would be visible in a few hours, not visible to the eye, but sometimes when a steam drill gets stuck or something of that kind, there is a movement in a quarry where there are very steep

slopes. My statement about that was that it seemed to me this thing might have occurred thousands of years ago, as the rock in most places is covered with from 4 to 10 feet of earth.

Mr. Holden. I would like to inquire whether any air forms around the air-valves at any time when the water is drawn from the pipes. Do you have to open these valves every time it is drawn off?

Mr. Taylor. Very rarely. There are one or two summits which occasionally give a little trouble, but usually the velocity through the pipes is so great, it pulls the air along with it. I think that is the solution of it, because there is a considerable amount of air which has to go, and I think it is mixed with the water as it passes on its way to the reservoir or to the village. The first filling of the pipe line took a good deal more time than we anticipated, because in addition to the eight or nine summits which were treated by these small blow-off pipes, there were other minor summits, and those in the first filling of the pipe also tended to retard the flow of water very materially; but since the first filling they have given no trouble. And I think very often, when there is an accumulation of air in the pipes, it is carried along with the water from the fact of its being under considerable velocity.

Mr. Walker. Did you clean out this reservoir or old mill dam, before you let the water in?

Mr. Taylor. Yes, but there was very little of it. Probably the whole contents of the dam didn't amount to more than 50 cubic yards or 100 cubic yards, so it was a very small matter.

Mr. Walker. Mr. Cook in his paper at Newport spoke about filling a new reservoir on natural ground, and he said there hadn't been any bad effects from it. Now on the Metropolitan system where they are going to fill a large reservoir, they intend to take out all the loam, which is quite an expense. It is a question in my mind whether they could not let a certain portion of it remain, but they say they intend to take it all off, where there is more than three inches. For instance, on the sides there is loam two or three inches on a sandbank, and they are going to take that off. Now Mr. Cook said he didn't have any bad effects from flowing a reservoir on the natural ground, without taking off the loam; and I would like to know if anybody else has had such an experience as that. It means the saving of a good deal of expense in the case of an in-

tervale, where there are no bushes or anything of the kind, if you don't take the loam off.

MR. TAYLOR. I suppose it comes to this, that the vegetable matter taken from the reservoir is so much poor material out of the way. In the case of the reservoirs at Worcester which have been in use a great many years, they have but very little trouble. At the same time those reservoirs are being somewhat improved, and that probably will do away largely with whatever slight trouble there may have been at times.

MR. COOK. The matter referred to by Mr. Walker is the construction of the new No. 3 reservoir of the Woonsocket Water Works. The dam was built and then came the question whether the reservoir should be cleaned or not, and as that would involve a large expense which the city could not afford, the material was left in it; and we haven't experienced any trouble either from the taste or the smell of the water which has been used from the new reservoir. The first season it was filled there was a slight scum formed in the shallow portions on the back side of the reservoir from the dam, and this season we didn't observe any at all. But I presume that that reservoir, situated as it is and used as it is, furnishes an unusually favorable condition for not showing any bad effects, because the water runs about two miles and a half to the pumping station, where the water is taken by the pump, and drops about 165 feet on the way, which aerates it, and probably any trouble there may be with the water when it leaves the new reservoir is gotten rid of in its passage through the open brook.

MR. COFFIN. I would like to ask if that is mixed with the water at the pumping station?

MR. COOK. Yes, it runs into the water at the pumping station.

MR. COFFIN. Does that make any difference in the quality of the water?

MR. COOK. No, because the reservoir at the pumping station is so small, I don't think it makes any difference.

MR. FULLER. I think something was said at that meeting at which Mr. Cook read his paper in regard to the possibility, or the feasibility of taking some of the money which it would cost to clean out this reservoir and use it to construct filters.

MR. COOK. That matter was looked into, and the expense of putting in a mechanical filter was estimated at about half the cost

of cleaning out the reservoir. But mechanical filtration being in the state it is now, there has been no attempt made to filter the water, especially as we have had no trouble otherwise than that the color is high. I cannot give you just the rate as compared with the Massachusetts reports, but I should think it is somewhere from about 70 to 75.

Mr. Metcalf. I would like to ask Mr. Taylor what sort of a regulating device, if any, was used for admitting the water into the reservoir from the upper pipe line?

Mr. Taylor. None whatever. The mains were entirely independent, that is to say, there was a direct pipe line from Gilman's pond to the distributing reservoir. There also was a connection between the distributing main and this main from Gilman's pond, and I think it actually is used directly from Gilman's pond, the upper reservoir. There is a somewhat amusing circumstance connected with that connection between the two pipe lines. Gilman's pond having, as I think, something like 408 feet head, I told them it was just as well to leave the gates open between the two lines. They couldn't quite understand why they wouldn't get the full head of water from Gilman's pond. I explained that the reservoir would act as a regulator for that. But some men selling supplies of various kinds almost convinced some of the commissioners that I must be wrong. At any rate, when I wasn't there, they thought they would open the connection between the two pipe lines and watch the result, having a man stationed to open a large blow-off on Main street in case the pressure gauge went up to an excessive height, and this was done. The gate was opened, but of course nothing happened, and so they concluded that they were all right. But there are the two pipe lines, and there are no regulating devices whatever on them. The superintendent wrote me only a few days ago that they did keep one of the main gates on the supply from Gilman's pond partly closed, simply because there was more flow of water through the pipe line than they wanted. There is almost always a certain amount of waste, and they wish to keep that waste down to the minimum. That is to say, the capacity of the pipe line is something over 400,000 gallons a day, and they are using only possibly half that, without any regulating device.

THE WORCESTER DISTRIBUTING RESERVOIR.

BY WALTER E. HASSAM, C. E., ASSISTANT TO THE CITY ENGINEER.

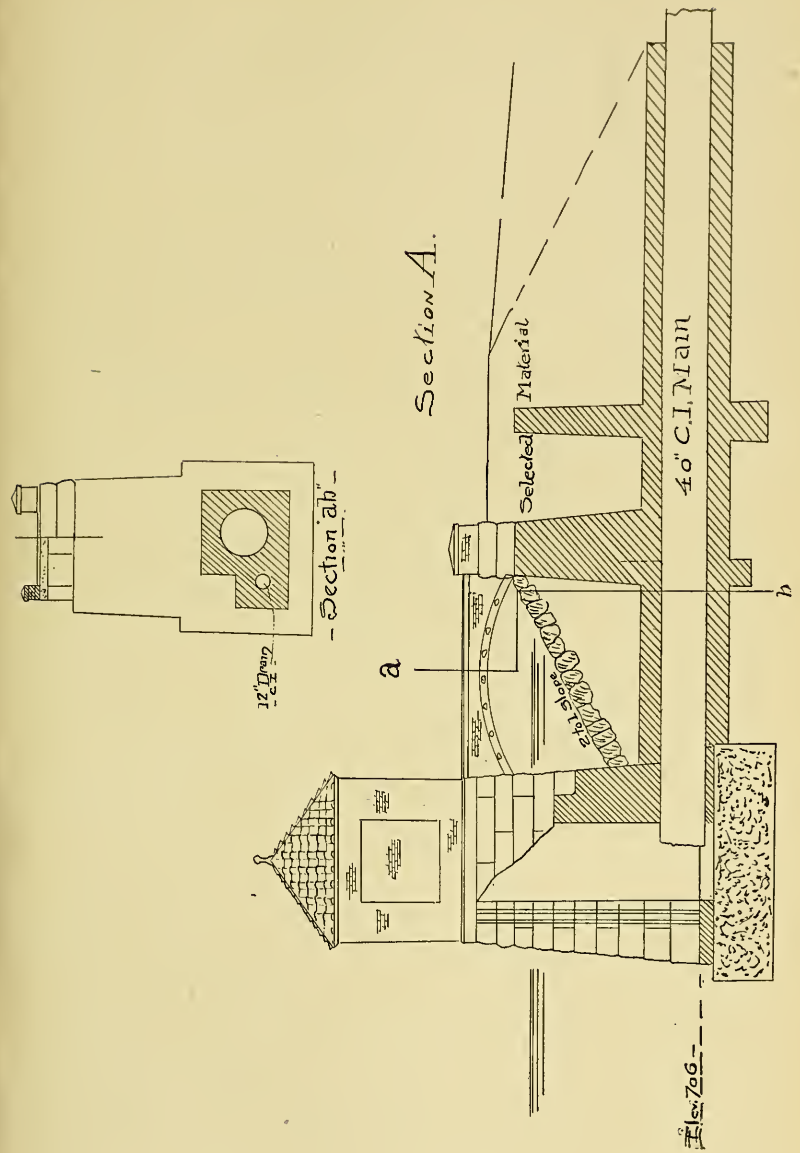
[*Read Jan. 12, 1898.*]

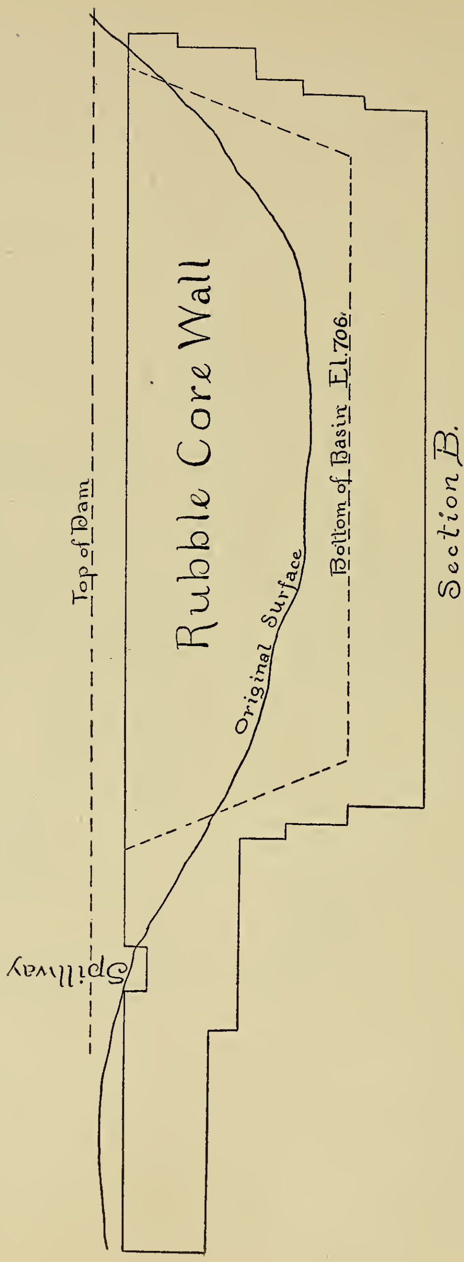
In the years 1893–4, it was apparent to the city engineer and some other officials connected with the water department of Worcester, that something must be done for a future supply of water for the fast growing city of Worcester, and it was decided that Kettle brook, flowing through the towns of Paxton and Leicester, with several large reservoirs situated thereon, and about 2300 acres water shed, was the best source of supply that could be attained. So the city secured the right to take Kettle brook above what is known as the Kent's Mill privilege, including all reservoirs above said privilege, ten rods around all reservoirs, and 50 feet each side of the brook. Several surveys were made, and it was found that near the Kent's mills with little expense, Kettle brook could be diverted into Lynde brook reservoir, the city's high service reservoir. The old dam at Kent's not being considered suitable necessitated a new one, and a new earth dam with rubble cement core wall was built, and the water diverted through a 30-inch pipe. As a great deal of this water is needed on the low service system, a cut was made in the Lynde brook reservoir to the depth of 26 feet, and a 30-inch pipe, encased in rubble wall, with two cut-off walls on the up stream side of the core wall was put in and a gate house of New Hampshire granite was also built. In making the cut in the dam the embankment was opened 12 feet wide and carried to a depth of 18 feet. The sheeting was cut three feet long and put in and well braced as the work progressed. At the depth of 18 feet two steps were made on the inside of two feet, and the cut continued in the same manner to the required depth, the last eight feet in depth being the same width as the wall around the pipe, and the wall was built against the banks with no side filling. After the pipes and walls had been laid the filling was spread in

2-inch layers and hand tamped, the sheeting being taken out three feet at a time, commencing from the bottom. The 30-inch pipe was continued down the valley about 4600 feet to the Parson's brook reservoir, which was under construction.

Parson's brook reservoir was built for distributing purposes only, having an area of 2.5 acres and capacity of 8,392,574 gallons, and 104.82 feet lower than Lynde brook reservoir, which elevation corresponds with the elevation of the proposed dam in Holden, on the low service system. Until this reservoir is built the pressure is equalized with the Holden supply, which is somewhat lower, with three 16-inch Ross regulating valves.

In making the surveys for the Parson's brook dam it was found that nature had done a great deal for us, for the exact elevation wanted was a suitable hollow surrounded on three sides by small hills, plenty of stone for core walls, and good material with sufficient clay in it to pack well for embankment. As Parson's brook flows through a boggy swamp and has only about two hundred acres water shed, it was not considered worth what it would cost to take it. So the course of Parson's brook was changed and carried around the reservoir on the west side by building a dyke. The earth on the site of the dam was excavated to a good foundation, which averaged 4 feet to 12 feet below the bottom of the basin. The trench for the core wall was carried somewhat lower, as shown by section "B." The basin was excavated to the elevation of 706 feet, and the slopes made two horizontal to one vertical, paved 1½ feet thick, 2 feet above and 4 feet below high water mark. This work was carried on at the same time as the construction of the dam. Thirty-six thousand cubic yards of material was taken out of the basin, which contained stone enough for the paving and core wall, also good material for the embankment. Section "A" shows the embankment 13 feet wide on the top, the up stream slope 2 feet horizontal to 1 foot vertical, the whole slope being paved the same as the sides of the basin. The down stream side was graded back with waste material from the basin 200 feet straight grade. The depth of the water in front of the dam averages 13 feet, the top of the dam 3½ feet above the spillway. The essential feature of the new work was the building of an earthen embankment, through which was a rubble wall. This wall is nearly in the centre of the embankment and was carried well into the east bank and into the


Section A.
- Section 'ab' -
40" C.I. Main
Selected Material
2 to 1 slope
12" Drain C.I.
a
b
Elev. 706


Top of Dam
Rubble Core Wall
Original Surface
Bottom of Basin El. 706
Section B.
Spillway

natural bank of the dyke on the west side, and built in the following manner: The stones were hauled on boats, washed free from dirt, and laid in the wall with plenty of Rosendale cement, well mixed, two parts sand and one of cement, great care being taken that no stone reached through the wall, which is 3 feet wide on the bottom and 2 feet wide on top. When the wall was brought to the height of about 5 feet above the foundation for the dam the embankment was started by spreading layers of clay material four inches deep, moistened (not wet) and rolled with a 3-ton grooved roller, the earth around the walls being well tamped with hand tampers. When the embankment was within 18 inches of the top of the wall, the wall was continued, then the embankment, and so on to the top.

The 40-inch main pipe and a 12-inch drain pipe through the dam are encased in rubble wall 6½ by 9 feet, with one cut-off wall of about 8 feet from the core wall on the up stream side. The cut-off wall protrudes 2 feet on the bottom and on both sides, the top being carried up to the top of the dam and acting as an abutment for bridge to gate house. The gate house is built on a concrete foundation, the sub-structure of New Hampshire granite, the structure of straw colored brick with marble trimmings, and the roof of copper. The bridge from the crest of the dam to the gate house is an arch concrete, with brick same as gate house for parapets and marble coping. Two posts at the end of the dam are built of granite, brick and marble cap. The floors of the gate house and bridge are concrete with smooth surface. In digging for the foundations of the gate house a pocket of quick sand was found with plenty of water. A well was sunk 6 feet square about 15 feet from the foundation in the direction the water was coming from, and the vein cut off. By keeping this well pumped, work could be continued on the foundation. The well for the gate house was pile sheeted with tongued and grooved plank, sunk 6 feet below the bottom of the reservoir and filled up with concrete, using Portland cement, the sheeting being left in. The other well was walled up in cement, 18 inches square, and the water left to rise as high as it would, then it was pumped out and filled with concrete, clay being tamped on the outside of the wall. In digging for the foundation of the dam on the west end another spring was found which was treated in the same way.

The spillway is 13 feet wide and empties into the canal or new course of the brook. The wing walls are New Hampshire granite. The wier stone crosses on top of the core wall and tongued into the wing walls. Both slopes are paved with street block paving and grouted with Portland cement. A gate was placed 24 feet from the entrance of the 30-inch supply pipe to the basin, and just back of the gate a 4-inch connection was made and the pipe taken under ground to the center of the reservoir, where a stand pipe was erected for a fountain; this adds a good bit to the beauty of the reservoir. The stand pipe is encased in a cement wall six feet square on the bottom and 4 feet on top to protect it from the ice. A road was built from the main road below the new dam to the main road below Lynde brook reservoir, a distance of about one mile, it crosses the stream just below the new dam, follows the east shore of the basin and crosses again just above the basin, thence over pipe line to Lynde brook reservoir. Two small rustic bridges 16 feet long and 8 feet arch were built where it crosses the stream. The arch was built of field stone, laid in Portland cement. The parapets are made of selected cobble stone, the top of the parapet left ragged. This makes a very durable bridge and also pleasing to the eye. The water from this reservoir is measured by a Venturi meter connected with the 40-inch pipe, about fifty feet lower than Parson's brook reservoir.

DISCUSSION.

MR. L. TAYLOR. I suppose the use from this reservoir is three or four million gallons per day?

MR. HASSAM. That is what they intended to use.

MR. ALLIS. May I ask what the size of the watershed is which supplies that amount of water?

MR. HASSAM. At the present time the watershed which we can draw from through this 40-inch pipe is over 4300 acres.

MR. L. TAYLOR. I would like to ask what that new gate-house in the enclosure of Hunt's reservoir is for?

MR. HASSAM. That is the house for the Venturi meter on the 40-inch main pipe.

MR. WHITNEY. Have you made sufficient tests with this Venturi meter to determine its accuracy?

MR. HASSAM. I have not made any experiments or tests with

this Venturi meter, but I had supposed it was acknowledged by most engineers that these meters are almost absolutely correct. In Holden we have a large reservoir that holds in the vicinity of 740,-000,000 gallons of water, below that we have a small distributing reservoir, and just below that distributing reservoir is a Venturi meter, which we have tested in this way: We have put in a weir just above the small reservoir, and measured the water over the weir, and then measured it through the meter. We have found the two measurements to correspond. That is the only way we have ever, to my knowledge, tested the Venturi meter.

Mr. L. Taylor. I would like to have Mr. Hassam state, for it may be of interest to the association, the number and sizes of the Venturi meters in use on the Worcester water works.

Mr. Hassam. There are four in all; two on the 30-inch high service pipe, one on the 40-inch pipe, and one on the 30-inch low service pipe.

BACK FILLING TRENCHES.

BY E. A. W. HAMMATT, C. E.

[*Read Dec. 8, 1897.*]

As my experience and observation has been chiefly in connection with contract work in suburban or country towns and cities, it may well have been different from that of some present, and if what I have to say shall bring out a good discussion on the subject, I shall have succeeded in my object.

I think that most, if not all present, have seen trenches back filled in such a manner that the street was left with a ridge from 4 to 7 feet wide, and from 6 to 10 inches higher in the centre than the original surface; and if you had an opportunity to observe the locality while work was in progress you also noted the fact that considerable material had been carted away as well. This condition of things is not, or has not been exceptional, but practically the rule, and as back filling is too often done it must be expected.

The usual back filling crew of say twenty to thirty men, will seldom have more than five or six rammers, and those do not do one-half the work they might, if intelligently directed. Quantity, rather than quality seems to be the object of the average foreman on back filling. The idea seems to have been that settlement was unavoidable, and that to save labor and expense, the trenches should be left well crowned, and be compacted chiefly by travel.

On the average country or suburban road of twenty or twenty-five years ago, this practice was not so objectionable as it is today, when so much more attention is paid to the shape and character of the road surface and we find such a larger proportion of streets macadamized.

What are some of the results of such practice?

First, we have a very unsightly and often dangerous street to travel over, and one which it will take months to get into respectable shape, if it can ever be done without practically resurfacing the street. Next we get a settlement immediately over the trench

with two ridges or shoulders where the filled material is placed on the undisturbed earth adjacent to it. These shoulders prevent the surface water from rain or melting snow from reaching the gutter, and confine more or less of it to the hollow over the trench, where it must soften the road surface and result in making such hollows and depressions worse.

Third, if by accident a large part of the original road surfacing material does not get carted off as surplus, it is placed in these ridges and in the crowning of the trench, and gets carried off when these are picked down, as they must be, thus robbing the road of that which should be most carefully retained.

It is customary to insert a clause in specifications, that a contractor shall keep his work, including road surfaces in good repair, for say six months after the completion of his work and make good any settlement which may occur during that time, the work to be in all respects in good condition at the end of that time.

In my opinion this clause is responsible for at least a part of the trouble. The contractor will usually say, and I think with reason: If I am to be responsible for six months, and must make good all settlement occurring during that period, as a matter of economy if nothing more, I must leave my trenches with a good crown—I can not afford to come back here every week or oftener to refill every little settlement that may occur; and if at the end of the six months the trenches have not settled down level, I will then cart off the surplus. If they have settled below the level, I will make them good.

Still another result of this method of back filling is that usually a crust is formed on the top of the trench, and when the shoulders above mentioned are removed, or the top of the trench cut down, this crust is broken and water soon finds its way under it, and considerable settlement often occurs. Usually this does not take place until after the time limit during which the contractor is to keep the work in repair has expired; and so the town has to stand the expense of doing work which it was supposed had been paid the former to do.

I claim that this is all wrong, and that better results are not only possible, but that we as engineers and superintendents should see that they are obtained.

Back filling should be done with the object of protecting the pipe or other structure and restoring the surface as nearly as possible to its original condition *and in permanent form.*

Let us consider for a moment some specifications regarding back filling.

Date 1875. "Earth filled into the bottom of trench, under and to the top of the pipe shall be carefully packed and well rammed with proper tools for the purpose.

"The earth filling above the pipe shall also be sufficiently packed and rammed to prevent after settlement; it shall be moistened when deemed necessary by the engineer and the material shall be free from stones over 6 inches in diameter. In streets and roads, the class of surface before existing shall be replaced so as to be in every way equal to that surface in material and workmanship, and satisfactory to the engineer."

The difficulty with this seems to me to be partly in the different views of different men as to what will constitute "sufficiently packed and rammed to prevent after settlement," thus raising a question during construction which cannot be definately settled until construction is over, when it is too late to do any good, and the omittance of any reference to the relation vertically between the original and the restored surface.

Date 1882. Another example is as follows: "Great care shall be had in refilling trenches, that the earth is carefully packed under and over the pipes and that the surface or road material is carefully replaced for 18 inches in depth."

It would seem as though under this specification—"most any old thing" would fill the bill, and as I recollect it, when I saw some of the trenches, I should say it did.

We next find a requirement that the back filling shall be put in in layers, not exceeding a certain thickness (variously stated to be from 4 inches to 2 feet) and thoroughly rammed or puddled.

This, I think is a move in the right direction, if the thickness is not made too great; but it is very hard to get it honestly done.

Then comes the attempt to regulate the proportion of rammers to shovelers, and in this connection I would say that one superintendent of streets remarked to me one day: "Hammatt, why do you water works men always get the cart before the horse? You put about five shovelers to one rammer on back filling, when you ought to put

five rammers to one shoveler. Then your trenches might stand."

We all know that authorities say that earth taken from bank and put in fill will shrink, and I think most of us have had an experience in setting a post, that after placing the post in the hole, we could pack in all the dirt excavated, and like Oliver " want more."

This raises the question, why cannot we get more of the material excavated from trenches, put back. I venture to say that we can, and I understand that in at least one case, all the material excavated was put back, and no ridge left. It is scarcely necessary to say, there was no after settlement.

Some authority states that the average shrinkage of various earths is about as follows:

Gravelly earth	8	per cent.
Yellow clayey earth	10	"
Light sandy earth	12	"
Puddled clay	25	"

If this is correct, we should have in a trench 5 feet deep and 2½ feet wide, giving 12.5 cubic feet per running foot, a shrinkage in the case of

Gravelly earth	equivalent to	a depth of	0.40	feet or	1.00	cubic feet.
Yellow clayey earth	"	"	0.50	"	1.25	"
Light sandy earth	"	"	0 60	"	1.50	"
Puddled clay	"	"	1.25	"	3.12	"

Taking into account the average thickness of water pipe of the various sizes as given by the tables of certain foundries, we find that per foot, the following is the number of cubic feet of space occupied by the pipe:

6-inch	about	0.27	cubic feet
8	"	0.44	"
10	"	0.69	"
12	"	0.96	"
14	"	1.29	"
16	"	1.66	"

From the above it would seem that when the pipe laid are not larger than 12-inch, we ought to be able in the average water pipe trench, to get back all the material excavated and leave no ridge, and that even with 16-inch pipe the surplus ought not to exceed about 140 cubic yards per mile of line—or 2.6 cubic yards per 100

feet. It would indicate also, that with 6-inch pipe, it would be possible to refill all the excavated material and leave about 4 inches in depth of trench to be refilled by borrowed material—or with 8-inch pipe about 2 inches. How often is this done? Different materials require different treatment in order to get the best results in back filling. Therefore I question the advisability of too much detail as to methods in drawing specifications.

If I recollect correctly, Mr. Fitzgerald, some years ago, stated as the result of some experiments conducted by him, that in all cases he secured the best results by dry ramming in thin layers, and Mr. McClintock found the same thing with regard to sand, gravel or loamy material, but would use water in clay or hardpan. We must remember that in these experiments, a considerable admixture of brains was also used, and that with the ordinary labor employed in contract work we can expect but little of this commodity.

Thorough ramming is hard work, especially with the style of rammers in common use, and the average laborer will do as little of it as he can.

I am inclined to think therefore, that in general, better results will be obtained by the liberal use of water than by trying to depend entirely on dry ramming; but if water is used, it must be used liberally to do any good, and even with its use a certain amount of ramming must be done.

I think too that better results in ramming would be obtained by the use of a rammer of different shape and weight from that commonly employed. The rammer in commou use weighs about 20 to 25 pounds, and has a diameter of about 6 inches. As ordinarily operated by the man using it, it is lifted about 2, or possibly 3 inches and allowed to fall, giving a blow representing the energy of say 5 foot pounds, distributed over an area of about 28 square inches. A rammer weighing 5 to 6 pounds lifted 1 foot would do the same work, and if some muscular energy were added to the downward blow, would do more. Now the lighter tool could be lifted much easier, the man's muscles would not get tired so quickly, and in my opinion a rammer having an end section not exceeding 8 to 10 square inches and weighing not over 6 pounds, would give far better results than those in present use.

In using any form of rammer, it must be remembered that the

ramming will affect but a comparatively thin layer, and so I think we are justified in requiring the back filling to be done in layers not exceeding 4 inches in cases where ramming is depended upon to settle the trench and thiner layers would be better in most cases. As much care should be taken in back filling trenches for house connections or service pipe as for those on the main line. I recall a case a few years ago, where I was notified that the contractor doing some work under my direction, was not properly back filling his trenches, as complaints had been received of dangerous holes on a certain street. Upon investigation, I found that a service pipe had been put in the day before by the superintendent of the works, and the trench back filled sometime in the afternoon. When I reached the place the following morning, the service trench, from a point over the main, clear across the street had settled, parts of it all of a foot, and none of it less than 6 inches, and the only depression I could find on the main line, was at this service. This simply shows that contractors are not the only people who sometimes slight their work.

To sum up, I hold that back filling should be done in such a manner that where the pipe does not exceed 12 inches in diameter, all the material excavated shall be put back into the trench, and the surface left smooth and with no appreciable ridge, care being taken that the original character and quality of the road surface is restored. When larger pipes are laid it would be comparatively easy to fix the amount of surplus material which would be allowed, which surplus should not contain any of the original surfacing stock—which should all be used to resurface the trench. In no case should the material used in back filling be allowed to be spread wider than the size of the trench excavated, as if this is done, shoulders which will retard or prevent surface water from reaching the gutters, are unavoidable, and they must eventually be picked down and removed. This is more expensive than to refill a slight depression, and usually means the carting off of road metal which ought not to be removed. I also believe that instead of requiring the contractor to keep the trenches in repair for six months, a certain percentage of the contract price should be retained for that length of time for the purpose of making repairs which may become necessary, but that the repairs should be made by the town.

DISCUSSION.

Mr. Hyde. In our city if we fill trenches higher than the grade of the street there is trouble. They require us to leave the trench at the same level as the old road bed, and we usually have very little trouble in doing that, by putting in plenty of water, and getting about all of the material back, and most of the time all of it back, except, of course, in clayey ground where we can not use a great deal of water. We usually do use water enough to carry the dirt all around the pipe and perhaps a foot or so above, but we can't wet it much more than that because it would leave it muddy. Then it has to be rammed. But otherwise, on mains and service pipes, we usually water, and if it is grass ground we take up the sod and lay it one side, and then the loam, and then throw the gravel on the other side, and we put the gravel back with water, and lay the sod back even with the turf. In nine cases out of ten that can be done.

Mr. Hammatt. There is one point I hoped I might get some light on. I have had the greatest trouble in back filling a trench in pure clay, and I hope there is somebody present who can give some information as to the best method of handling that kind of material. You take a clay which will cut out, like a cake of cheese, and throw it out onto the bank, it lies there in lumps, and there is just moisture enough in it so it won't break up, and when it is thrown back into the trench, if you try to ram it your rammer slips over it like so much ice or grease, and water won't have any effect on it, as usually tried at least. I hope there is some one who can give me some idea of the best method of handling that. I suppose if it could lie on the bank long enough to get dry and break up, you could put it back all right. At any rate, I know a material holding a good deal of clay that will dry out and pulverize, and can be put back about as well as anything I ever tried. But you take the clay such as I first mentioned, and I don't know how to get it back in any decent sort of shape, so that there won't be any settling. I never succeeded in doing it and I have never seen it done.

Mr. Haskell. The gentleman has covered the ground perfectly in my opinion when he suggests the idea that the nearer you get it pulverized when it is put back the nearer you come to getting a good job. His statement about putting in four inches in depth at a time and ramming it could only be bettered, perhaps, by changing it to

putting in two inches at a time in clay. Any amount of moisture in the clay will make the work of getting it back more difficult. It is entirely impossible to ram clay that is moist, and the greater the amount of moisture the more impossible it is. I have found it almost impossible to get back the whole of certain clays. There are gravelly clays that you can put all back. Any other material I have ever found in our streets can all be put back, even if you should dig an excavation 25 feet deep for a 12-inch pipe. The only difficulty in getting back the material is requiring the men to do it. It is perfectly feasible to do it, and we always oblige our men to do it. Where we do the work by the day, and all of our work is done by the day, we put the whole material back except in certain clays. There are some clays we don't succeed in doing it with, which I have never been able to get back.

Mr. Winslow. I can't give any experience in the clay, but perhaps I can give some experience in other soils. My method used to be to put the earth back and ram it, and I found that Mr. Hammatt stated the fact when he said that a rammer didn't work well in the hands of the ordinary laborer; it is too much work, and the heavier the rammer is, the poorer the earth is rammed. I used rammers weighing from 8 to 10 pounds, and found those worked better than the heavier ones, but those didn't work to suit me. The outcome was that I put enough water in the trench so that when the material was thrown into it, it would sink in the water, and that would wet it thoroughly, and in most grounds it would not settle after being filled. The last of the trench filling I would put in dry, and ram it, so as to give a chance for teams to pass over without getting into the mud. But even that did not really suit me. I have found that the contractors whom I had to deal with for the last year and a half, will do all that is required on the face of it. They will either ram the earth put back, or they will put water to it "in sufficient quantity?" The question is, what is a sufficient quantity, and I find that where they pay 25 to 30 cents per 1,000 gallons for water to put into a trench, their idea of a sufficient quantity is very different from mine. I haven't been really satisfied in a number of cases where it has been done. They say they have the roads to take care of for six months after the work is done; the rains will settle it if there isn't sufficient water, and then they will fix it up. The consequence is that water is used rather sparingly in a great many cases, and with-

out doubt there will be some places to be fixed up within the six months specified.

But in speaking of putting in water to settle the earth, I was shown a scheme this last summer that I think is the best for puddling a trench of anything I have seen.

On Massachusetts avenue, Cambridge, there was a contractor from Medford who put in a 48-inch pipe in a trench averaging, I should say 12½ feet deep. It was deep enough so the 48-inch pipe went under all other water mains and sewers, and in fact all the pipes of the city of Cambridge; none of them were removed. The contractor wanted to fill the trench with no ramming and with no water. I asked him what he took me for? Well he says, "I can do that, and I will make it all right." I said, "how will you do it?" He said, "I will shove a pipe down into the ground and I will completely saturate the earth with water, and it will put it back there so it will not settle at all after I get through, and after I put a steam roller on."

The result was I allowed him to do the work that way in Cambridge. I talked with my division engineer with regard to it. He didn't take kindly to it, but we finally concluded we would let him try a little to see how it worked. Accordingly he filled the trench with this sandy material, or whatever it was, it works the same in all cases. He filled the trench within about a foot, and then hitched onto a hydrant, with an ordinary fire hose, with a play pipe about 20 inches long with about an inch and an eighth nozzle, I think. A 2-inch meter was attached which allowed only about 75 gallons of water a minute to go through the hose. He would shove the pipe down so it would come within 3 feet of the bottom and let it play until the ground settled, and then he would pull it out and shove it down again. When the ground stopped settling and the water came to the surface, he would start over again 4 or 5 feet away and do the same thing, and so zigzagging along up the trench. After getting all the water in he wished to he would then even it off, put on his top material and use rammers, and leave it fairly well crowned. This trench was 7 feet wide, and after letting it stay for a few days, perhaps a week, he put a steam roller over it. The consequence was it put the street down, very nearly, if not quite as well as it was before, and I doubt if it settles a great deal in time to come.

There is another matter to be considered, and that is the cost.

In Somerville, this contractor paid $200 for the water to puddle the trench, using what he wanted. In Cambridge he paid for it at the rate of 30 cents a thousand gallons, and he puddled the trench satisfactorily, and his bill was a good deal under $200, which was the price which they wanted for the water to take it in a lump sum. And you can see that to fill the trench so that when the gravel was thrown in, it would fall in the water and be thoroughly wet before it would go to the bottom, requires a surplus of water over and above what would be required to simply fill it to saturation.

Mr. Gilbert. I am a firm believer in the use of water in filling trenches. I think its use cheaper than ramming and it is much more effectual in my opinion. But I believe you have got to use the water very liberally. In my experience the more water you can get into a trench and not have it overflow, the better job you can do. Of course it makes some difference what the material is that you have to put back. Our streets are mostly macadamized, and we are obliged to be very particular to get all the material back, and with the size of pipe that we lay, by taking pains and using plenty of water, we can do it. Sometimes in putting in services it is almost impossible to get water, and in that case we do it by ramming. But it is a very difficult matter I find to ram material around the pipe, or in any bad place, and get it all back, so but what it will settle some afterwards.

I had an experience last week. I dug a trench across the street about 50 feet long, and had the dirt all thrown out, and one of those cold nights it froze up, and it froze from 3 to 4 inches deep all over that dirt which was to be put back. After putting in the pipe, the workmen began to pick up the dirt to put it back, and it was in large chunks and very solid. I hardly knew how I was going to get it back, because it was where they had got to drive over the trench immediately, and I wanted to get it back in as good shape as possible. The idea struck me that if I would take all those large frozen chunks and throw them in the bottom of the trench, I might settle the fine dirt around them and get it all in in that way. So I had it all picked over and had all the chunks thrown in the bottom of the trench, and then we filled the trench about two thirds full of water, and then put all of the fine stuff back; and without using any rammers at all we got it all in and got it down level with the grade of

the street in good shape. I think it is very much cheaper than ramming without water.

Now speaking of filling trenches when you are laying mains. Of course if a contractor takes a job to lay a line of pipe, he makes his price according to what he has got to do. If he has got to put the material all back and get it down to the surface, he has got to get his pay for it, of course. Now, in back streets, where there isn't very much travel, of course the cheapest way for any town is to throw it back and let it settle itself. It makes rather a bad looking street, but I notice when the work is done in the fall, by waiting till spring it gets down in good shape, and it doesn't cost near as much as it does to pay the contractor for ramming it.

Mr. E. A. Taylor. We have found the method which has been mentioned, of filling to near the surface and then puddling, the most satisfactory way we ever tried. This plan which Mr. Hammatt suggests, of having five rammers to one shoveler can't be carried out at the present contract prices. Last week I had occasion to fill a trench with frozen ground, and some of the lumps were a foot in diameter. I would like to ask if anyone can suggest an economical way of treating them where there is no water to be had?

Mr. Hammatt. My friend suggests that the contractor can't afford to do the best work at the present prices. I think that is very doubtful myself, and I don't think we ought to pay present prices. I think myself it is poor economy for a town to have its work done in the way in which it is too often done, simply to save a few cents per foot on the cost of laying the pipes. I think they have to pay more in the end for fixing the streets than they would if they paid enough to have a good job done in the first place.

Mr. E. A. Taylor. I filled about two miles last year with a road machine, just scraping the dirt in, with no attempt to puddle or anything. We just scraped it in and crowned it over, and that was much cheaper than any puddling or tamping we could have done. It settled the first rain, and we ran the machine over again to fill the holes. We ran it over three times on one street. It was much cheaper for the town, and was satisfactory to them.

Mr. Haskell. I suppose that was in a town where the original condition of the streets, perhaps, was fully as bad as that left them in.

MR. FULLER. At Winchendon last year, the contractor back filled his trenches and crowned them up. He filled them with the scraper, and then took a four horse team and loaded it heavily, and drove it along, allowing one wheel to run over the trench, and it compacted it and made a very good job of it.

MR. HASKELL. The trouble with that sort of ramming is this: It will do a pretty good job right at the time, but it don't have any effect for any depth down into the trench. You can put a tumbler or a fine glass jar down two feet deep, a foot in diameter, and you could run a pretty heavy load over it and you wouldn't break the glass. That will show you how much effect it would have below the immediate surface that that wheel ran over; it certainly wouldn't extend down over 8 inches. It would get the contractor out of it very likely, but by next spring the trench would be back again just as bad as if that wheel hadn't run over it.

MR. FAIRBANKS. I represent Winchendon. Those trenches were filled with a scraper, as Mr. Fuller has said, and a four horse team was put on loaded with stone. At least 12 miles out of the 13 were filled in that way. Then they took the road scraper and went lengthwise, after the dirt was scraped in; and most of our streets were in as good condition in one week after the pipe was laid as they were before, and they have been ever since. They have gone through one winter and almost two summers.

MR. GILBERT. I had a steam roller run over a gate box the other day, and I guess if the gentleman had been there he would have made up his mind it went to the bottom.

MR. HASKELL. Anybody who has done much of any street work ought to be very well aware of the fact that he can't tell very much about what is under our streets. I had occasion once to dig a hole in a street where they seemed to be a very good surface. There was a sewer laid about 14 feet deep, and a team came along by and broke a hole through. The hole at its first appearance didn't seem to amount to much, but we put in 35 double team loads of small stones in filling that hole. The surface of the street was, as this gentleman says, apparently very good, but without a doubt there had been a small opening in the sewer and the under material had gone down into the sewer and been carried away. It didn't show on the surface at first, but time revealed it.

Mr. L. A. Taylor. I had an experience in Worcester. There was a sewer built about 13 feet deep through clay—hardpan, and the material was replaced by shoveling and some puddling; I think there was no ramming done, but it was replaced in fairly good condition. This work was done during the summer, and the next spring the street was paved with the ordinary square block paving. Twelve years after that—I was at that time in charge of the Worcester water works as superintendent—I was driving out to one of our reservoirs one morning, and I found that street for about 1,000 feet had settled from 8 inches to a foot. Well, the solution of the thing was this, that the pavement had made a comparatively water-tight crust over this trench, and the clay underneath had become gradually saturated, but it had taken 12 years for it finally to drop down and compact itself. I doubt if anyone in the city of Worcester except myself knew the occasion of that, but I knew all about it.

The President. A six month's guarantee didn't amount to anything in that case.

BACK FILLING TRENCHES.

BY E. H. GOWING, BOSTON, MASS.

[*Read Jan. 12, 1898.*]

I have been asked to tell what I know about back filling. It isn't much, and, after the paper read at the last meeting, it will appear to be very little indeed.

One item, however, seems to have been left out of the consideration, and it is an important one, too. It is the expense of having back filling done as the author of the paper referred to says it should be done.

This same matter of cost is, I think, too often left out of the question; as in the case of installing a high duty pumping engine in place of a low duty engine, when the interest on the saving in first cost, to say nothing of extra cost for repairs on the more complicated machine, is more than the increased cost of fuel, etc., required by the low duty engine; or, as when additional water supply for a city or town is obtained at great expense, when a less amount of money invested in meters, would stop the waste and do away with the necessity for the increased supply.

There is no question in my mind but that back filling can be returned to the trench in such a manner as to prevent after settlement, etc., etc., but does it in every instance pay, and are the authorities whose money is being spent willing to stand the expense?

An instance was reported to me of a contract being taken where Mr. A was the engineer, and where it was supposed that he would interpret the specifications, including the clause regarding back filling, and that he would interpret this clause in that town as he had previously done in others, and by the way, as he has done since. When the work was begun, in place of engineer A, the contractor found that Mr. B was to interpret the specifications, that his ideas were entirely different from those of engineer A; that he insisted

upon having the clause referring to back filling carried out to the letter, and according to his own ideas, and without any reference to those of engineer A. The contractor was caught, and in that case, the authorities got their back filling done as Mr. B thought it should be, and without paying for it. You may say the contractor was at fault in not bidding upon doing the work in the manner called for by the specifications. That opens up an argument upon which much might be said. For the purpose of this paper, it is sufficient to say that not one pipe laying contract in a hundred is awarded to the contractor who bids on doing the work strictly according to a literal construction of every clause in the specifications.

In the case of streets paved or carefully built, back filling should be carefully put back, and the original surface restored as near as it can be. The authorities should pay for it, and the contractor should make his bid high enough to cover the expense. But, in the case of country roads, where the pipe is frequently laid outside of the traveled part of the road, where but little expense has been incurred in building the road, where the original surface, as likely as not, is of inferior quality to the gravel found beneath the surface, I consider it quite unnecessary to go to the expense required by a literal reading of the average clause regarding this part of the work. When the pipe line crosses a street, more care should be taken; and, in the case of service pipes which almost always cross at right angles, it is desirable that sufficient precautions be taken to prevent too great after settlement.

In the spring of 1892, I wrote some specifications for pipe laying and called for a price per foot for pipe laying with the understanding that the back filling should be done in the manner customary in country towns, and, in case it was required, another price for thoroughly ramming the back filling. Practically the same specifications were used in two towns. In one, 2,500 feet were required to be thoroughly rammed; in the other, none. In one town there were four bids; two bids were five cents per foot and one each two and three cents. In the other, six bids; four of which were five cents, and one each, two and three cents per foot, the lowest bidder in each case bidding three cents.

Through the kindness of Mr. Fuller, who writes contracts with

an item for specially ramming back filling when required, I am enabled to give the prices bid for thoroughly ramming back filling in two other towns. They are as follows: In one town, out of eleven bids, there was one, eight cents; three, five cents; four, three cents; one, two and one-half cents; one, one and three-quarters cents; and one, one and one-half cents. The contract was awarded to one of the three cent bidders. In the other town, out of five bids, there were two, five cents; one, four cents; one, two cents; and one, one cent; awarded to the last.

These figures give some idea of what contractors of experience think it costs to back fill so there shall be no after settlement, and some idea of what should be added to the estimates for that purpose.

Now, as I said before, I do not believe this extra expense is warranted in the smaller towns. In a system having, say, ten miles of pipe, the additional cost would be from $1,000 to $1,500, without the work being any better. I think I say this advisedly, for those interested in works in such towns have, in almost every case, expressed themselves as satisfied with the work; and, from my contact with water works officials, am sure a large majority of them would prefer not to pay $100 to $150 per mile to have the trenches back filled in any different manner from what they were; for, in many towns, even such sums are considered worth saving.

I would like to protest against the form of the back filling clause frequently inserted; for I think this clause, as other clauses, should say just what it means, and mean just what it says, so that the bidder need not take the personal equation of the engineer into account at all, or have to guess as to the probable effect of having an inspector who will or will not enforce the specifications literally. The specifications should state how the back filling is to be done, and then it should be done that way. When the specifications say that it must be spread in 4-inch or 6-inch layers and rammed with heavy rammers, the contractor should not be allowed to scrape it in with a horse-scraper. Please understand that I think it right, in many cases to use scrapers; and were I building works for myself, or acting as engineer, would allow it when proper; but would try to write the specifications so that I would not pay the same price for

having the work done that way, as I would expect to pay for more thorough work.

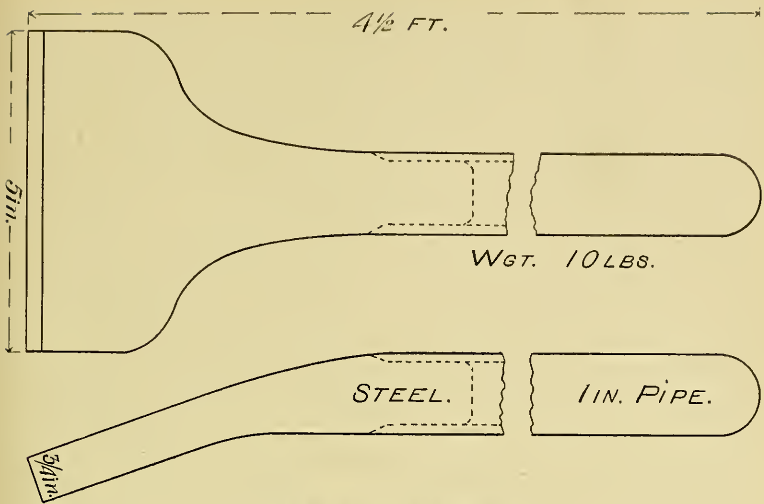
I remember seeing some back filling going on, some years ago, where twelve men were shovelling frozen earth, and two men were ramming with the tools and in the manner spoken of in the paper referred to. From my point of view, ramming, in that case, meant simply an unnecessary tax of $3 per day on the contractor, without the slightest benefit to the town for whem the work was being done.

You who have never undertaken a contract, may think the contractor likes such little things; but were you in his place, would not you think it was worse than foolish to be obliged to make the outlay when neither party to the contract was getting any benefit?

The author of the paper referred to says: "I hold that back filling should be done in such a manner that where the pipe does not exceed 12 inches in diameter, all the material excavated should be put back into the trench, and the surface left smooth and with no appreciable ridge, care being taken that the original character and quality of the road surface is restored," and I would simply add, "where the original character and quality is of such a character and quality as to require it, when it is distinctly understood beforehand that such restoration will be required, and when the authorities are willing to pay for it."

Speaking of the use of water for tamping, of course that is all very well in the case of ditches opened for any purpose in streets already supplied with water; but what will you do when the works are first put in, and when, as is frequently the case, the pipes are all laid before the pumps are set up and in commission? In that case, water could only be obtained at considerable expense; and it is just this expense which I believe, in many cases, we are not warranted in incurring.

What is said, in the former paper, about the tools used and the manner of using them, is true. I believe a rammer more like those used for tamping ties in railroad work would make a much better tool than the rammers now used. To show my idea of what a rammer should be, I have brought one to be used when required. This was made especially for tamping under large pipes which were laid to line and grade and supported on blocks and wedges.



RAMMER FOR LARGE PIPES.

The cause of the listless manner of men using rammers, one need not go far to find. What contractor, in the above instance cited, would put any but the laziest men on the rammers, and even the stupidest laborer, American or foreign, knows that he is mainly there for form's sake, and can you expect him to put any interest in the work? The fact is, "human nature" is a factor in work. Even contractors and their laborers have some of it; and when this important factor is taken into consideration and allowed for, there will be fewer differences between engineer and contractor, better work will be done and every one better satisfied.

DISCUSSION.

MR. FULLER. I think there is a good deal of justice in what Mr. Gowing has said, and it seems to me it would be much better in writing specifications to divide the matter into two parts, or two sections; that is, have a price for a ditch that is to be filled and rammed only under the pipe, and another price where the entire ditch is rammed. I have used this method in two cases and it has worked very satisfactory indeed. I think the trouble with the old style of specifications was, that the water commissioners, who knew very little about the thing and thought that they must have everything done as was specified, which, of course, was all right,

insisted on having a great deal done that was unnecessary. Now if certain parts of the streets require that the trenches shall be rammed, let them be rammed, and let the contractor get the price which should be paid for doing such work; and in other parts of the town, where there is little travel, where the roads are poor, it seems to me it is unnecessary to do much ramming. In the course of a few weeks or a few months the street will get down to about where it was in the first place, and it will be just as good as it ever was, and just as good as if it had been rammed down flush with the surface. I don't think I ever knew of a pipe being broken after it had been laid, because the trench had not been entirely rammed. So it seems to me it is much better to allow the authorities, the water commissioners, or whoever the persons in authority are, to say what streets and what parts of the streets they will have rammed, and let them be rammed, and let the contractor get his pay for it, and let the other streets go without being rammed so that the top is flush with the old surface. In that way, as has been said, a great deal of money will be saved, which ordinarily can be put into some other part of the work to better advantage.

Mr. Richards. I agree with Mr. Fuller that the ramming should be paid for, but as to where it should be paid for, it seems to me that it is largely a question of how much risk you are willing to take. For instance, if your ditch is improperly filled and settles, and somebody drives into it, five hundred dollars isn't a very large bill for damages, and that would pay for considerable ramming. (Applause.) If you are willing to take that risk, and are lucky, and nobody drives into the ditch, then you are all right, but if you are unlucky then you will wish you had rammed the ditch.

Mr. Hammatt. I don't think I should take issue with Mr. Gowing's remarks, nor, in the main, with those of Mr. Fuller. Yet I think there is one point which Mr. Gowing has spoken of where he has to some extent misinterpreted my paper. While I think I stated that my experience had been mainly in suburban towns, I, perhaps, should better have said in towns near Boston; and in the majority of such towns the character of the streets is such, that in my opinion at least, they all ought to be rammed. There are undoubtedly places where I would fully agree with Mr. Gowing that the thorough ramming which I advocated might well be omitted, or, at all events, a large part of it. But, as Mr. Rich-

ards says, it is largely a question of how much risk you are willing to take. As to the matter of the use of water, my paper, perhaps, was a little vague. Of course there are cases where it is practically impossible to get water to use to advantage. When I wrote the paper I had in mind more particularly the statement made some years ago by Mr. McClintock, if I remember rightly, advocating dry ramming entirely; and the point I wished to make was that with the ordinary contracting work you would undoubtedly get better results by using water than you would with dry ramming with the present facilities.

Mr. Fuller. I would like to say just one word in respect to what Mr. Richards has said in regard to accidents being caused by lack of ramming. In all my experience, with about a dozen different systems of water works, I don't remember ever having a single law suit growing out of any accident that occurred because the trenches were not entirely rammed. There may have been little accidents where a few dollars paid the bill, but there has been nothing at all serious, nothing where the money paid out would compare with what would have been paid for the extra ramming.

Mr. Richards. Mr. Fuller has been very fortunate, and he is to be congratulated.

Mr. Gowing. I think I have been just as fortunate. I have had to do in one way or another with between 250 and 300 miles of pipe, and I remember but one case where there was any accident which really cost anything, which could possibly be laid to lack of thorough ramming in the ditch, and I am not so sure about that, because it occurred in a low place after a heavy rain, and the ditch was filled up with water. It was thoroughly puddled, and after it was dried out there would have been no trouble. But a team ran into it one Sunday morning, (when the people had no right to be out under the law), and on account of the ditch being so thoroughly puddled and wet, the wheels sunk in and a woman's dress was spoiled, and it cost $50 to settle for that. But it is the contractor who has to pay for all these things, he has to take all the risk; it doesn't come on the town.

Mr. Haskell. Of course, as we are talking this matter over we see all sides of it, and I think we are all aiming to get at the same thing. My idea is that the engineer should write the specifications to cover the particular work there is to be exe-

cuted. Out in the woods, where the road has a good many dangerous places in it, as we may see in riding around in the country, there are undoubtedly a good many places where you could put the dirt back with a scraper and leave the street better than it was before you went there, Any sort of work would *go* there. But I have seen a good many instances in the city where water pipes have been laid in paved streets, and I have sometimes as late as a year afterwards, seen places where the paving had settled down so the street was dangerous. I have known cases where hundreds of feet of paving had to be taken up, and more material put in and the street repaved. I have known that to be done four times on one street. Now, if the work had been done properly the first time, even at quite a heavy expense, it would have been on the whole cheaper, than the final cost of the work. As to the risk of expensive results from accidents occasioned by poor back filling in trenches, I can cite one instance where a contractor put the back filling into a trench in the street, and there came a storm and it settled, and he had to pay $10,000. A man driving a milk wagon came along in the morning and tumbled into the trench, the team was smashed up, and the man was badly smashed up, and there was a $10,000 verdict at the end of a lawsuit.

The President. Mr. Gowing, have you anything to say about that? You see the contractor has to stand it.

Mr. Gowing. He can stand most anything; he has to. (Laughter.) I do not want to be misunderstood as entirely disagreeing with Mr. Hammatt, for I intended to bring out the idea that in certain places it is necessary and desirable that the trenches should be back filled as well as they possibly can be. In such streets as Mr. Hammatt speaks of, in the vicinity of Boston, I should believe in doing it as thoroughly as he would; but I mean to say there are places out in the country where I do not think it is best to do it in that way.

Mr. Chace. I should like to ask either Mr. Gowing or Mr. Hammatt whether they believe in putting back the back filling in such a way as to leave the surface of the ground flat when they get through, or whether they would leave a small ridge to allow for future settling.

Mr. Gowing. I meant to leave a mound. Of course when back filling is put back in that way it means it has got to be watched and looked after. I did some work a year ago, for a gentleman who is

in the room, and after we got all through I said to him, "Now, that ditch is going to settle some, and we are not to be in town; won't you look after it and let us know what the bill is and we will pay it?" That was satisfactory to him and it was to us, and when the bill comes in, if we are not in the poor house, we will pay it.

Mr. Hammatt. In that connection, from my experience, I believe if the trenches are properly back filled they should be left either flat or with a crown not exceeding 2 inches. And I believe that largely for this reason—I am speaking more particularly now of streets where the surface will warrant the thorough back filling mentioned:—if your trench is left crowned with the idea you are going to have future settlement, and that settlement does not take place, that material that forms the crown, to make your street in proper shape, has got to be picked off and carted away. Now that will either be the very best of the road material, and you are carrying off what ought to be left on the street, or even if it is not road material but any other material, makes an expense either to the contractor or to the town which is unnecessary. It is more of an expense, as a rule, to cart off from 4 to 6 inches of material than it would be to put on 2 or 3 inches of road material if the trench should settle a couple of inches. From the experience I have had with towns they very much prefer to cart in 2 or 3 inches of road material to make the street good, than to pick off and cart away from 4 to 6 inches of whatever material there was there.

Mr. E. A. Taylor. The main point under discussion really is the wording of specifications. I think they should be worded differently according to the different conditions to be met with in different places. One incident will illustrate what I mean. We had about two miles of pipe to lay recently through fields, crossing only one road. The clause which referred to back filling was plainly written for city streets, because it referred to paving, macadam, and so forth. The inspector had one idea about the back filling, and we had another, so the engineer was appealed to, and he said: "Well, it will all depend upon how much you are inclined to kick." We didn't kick much, but the result was we were allowed to back fill the trench without any ramming except where we crossed the road.

Mr. Beals. The remark that the gentleman has just made covers a good deal from the commissioners' standpoint, "how much

the contractor will kick." I never could quite see why it should be put in the specifications that the trench shall be back filled and puddled and tamped and all the material returned to the trench, and then when you ask the engineer why the contractor doesn't do that the answer will be, "They never do it;" and then comes in the point how much the contractor will kick. I think it makes a good deal of difference about the material in the streets. In some of the streets in Middleboro the material is of a very peculiar nature with regard to filling. I have a case in mind that happened on our own works. The job was apparently well done, the material, perhaps all of it, put back in the trench, and the street left with a good surface, and some four years after the work was done, one wet night a hack drove up to a house on the same side of the street that the water pipe was and two of the wheels went into the trench, giving the hack a wrench, and the result was that the owner of the hack got almost a new hack out of it. It needed repairs, and the water board had to pay for it. That was because the trench underneath, the lower part, had settled, and left a good hard arch which stood there for three or four years, until it sunk away one wet night and let the wheels of the hack through. And about that same time we discovered a similar condition of things on one or two other streets. The result was we put our men upon every place where we suspected there was such a settling, and picked the earth all down till we reached solid material, and then carted in new material, and I believe, with one or two exceptions, we haven't had any trouble of that kind since. Our soil is of such a kind that some of it will settle hard and some of it will settle with an arch.

I recollect an experience we had in laying an 8-inch pipe. There were perhaps 300 feet of it, and we had to hurry up because we were right alongside of a store with two or three entrances, where they drove up for loads of grain and other things, and we wanted to get the trench dug and the pipe in as quickly as we could. When we got our pipe in it was approaching night, and we wished to get it filled before night so we hurried up the filling without keeping up to the specifications, (we were doing it ourselves, however, and not under contract), and we filled about 150 feet of the trench leaving it a little crowning. The other 150 feet we had good opportunity to both ram and puddle, and we did it thoroughly, and got all the material in, and it didn't quite come to the level. But it so hap-

pened that within eight or ten weeks we had a horse in that trench that we did so well, where we got all the material in and didn't quite fill the trench, and we had to settle as easily and peacefully as we could, without making any more noise about it than necessary. For you know what a temptation there is if anybody can drive a horse into a ditch without getting hurt, to do so and then claim damages. Our experience in that case was that the work we thought we had done the best was what the damage resulted from.

The material we have is a hard, marly material, a mixture of clay. During the summer time, when dry, it picks up a good deal like cement, and when it is wet it picks up like pudding, soft. There are one or two persons in the room who can appreciate the kind of material we have in some of our streets, and what treatment it needs in filling. I have had the best results from dry ramming, and I prefer a rammer like that which Mr. Gowing has shown us, rather than a round one; because the trouble I have found usually has been where the material has been wet and then dried out and shrunk, leaving a crack between the new material and the old side of the trench, and the water pours down through the crack and softens up the new material in the trench. From the experience I have had, (I haven't had as much as many others here have) I have found that if you ram right close to the old hard earth, so the water won't get a chance to get down there, there is less danger from settling afterwards by the earth filling up with water and softening, than there is if you use a round, heavy rammer and ram the whole trench across. I think I have had better results in just seeing that the edges are thoroughly rammed than in trying to ram the whole.

The President. Mr. Taylor cited a very interesting instance at our last meeting, of the settling of a trench after a long time.

Mr. L. A. Taylor. That was a case of a sewer trench, I think, after eleven or twelve years. The reason that it kept up so long was undoubtedly because the street was paved the year after the sewer was built, and it was probably owing somewhat to the kind of material. As Mr. Beals says, the kind of material is a very great factor, and engineers should, it seems to me, make their specifications according to the circumstances, instead of using precisely the same wording in every case, as they often do. I have laid water pipe, for instance, in Provincetown, where there is nothing but sand about the size of granulated sugar, and there is no more use to tamp

it than there is to tamp water. The trench would be from 8 to 12 feet wide on top for a trench 3 feet deep. I have also done work in Middleboro, and, as Mr. Beals says, when that soil becomes saturated it is almost a quicksand, and when it is dry, after it has been on the bank for a few days, it is almost like concrete. It is precisely the same soil, but the difference is in its being saturated with water. So the character of the material should be taken into consideration in back filling trenches, because there are so many extremes. I have also laid a line of pipe some six or seven miles through private fields. The specifications called for tamping it all, through cornfields and woodland and stumps and roots and all that sort of thing, but of course it would be absurd to do that. Of course where we cross the small gullies and rivulets, we have to look after those places anyway. So it seems to me that in making specifications it is somewhat too common to follow the stereotyped form, and then when the work is let simply tell some of the contractors it will be done about so and so, and some other contractor who don't know about that will take the chances. Of course in suburban towns and cities there is no doubt but that the best work which can be done is what should be done. But in country towns in the northern part of New Hampshire or Vermont or down in Maine, it would be useless to ask them to pay $150 to $250 a mile, which might mean $1,000 or $2,000 additional cost for the works. They wouldn't pay for it, it wouldn't be expected and it wouldn't be necessary.

THE PRESIDENT. Mr. Hazard, you have had experience, can't you tell us something about this matter?

MR. HAZARD. My experience has been limited. I agree with Mr. Richards, that we can't afford to have trenches cave in after they have been back filled. My experience has been that if you fill them in a hurry, put the dirt in anyhow, the dirt will form a sort of arch over the top which will stand up for some time, and you will never know when you are going to get a cave in. It may come in one year, and may not come in ten years, as has been said. I have seen sewer trenches which caved in after four or five years. A horse would go along and happen to step very heavily and would break a small hole through, and you would find that the whole trench was undermined, that under the surface there was a cavern, and the top of course, is liable to go down at any time.

I have had several cases where we had to back fill sewer trenches outside of the limits of the water supply. The way we have always managed in such cases has been to fill the trenches up to within about 4 inches of the top of the ground, and then leave them until it rained, and we have almost always got them settled in good shape in that way. Sometimes, of course, you have to wait quite a little while, but we have always thought it better to leave them in that condition for two or three weeks even, rather than to fill them up and have them settle after two or three years. Generally if you leave 3 or 4 inches of depression on top till it comes a good soaking rain, the water will stand right there and settle it down thoroughly. Of course that isn't as good as if you had plenty of water to put in as you are putting in the dirt. I will say I have had the best success in putting back earth by filling the trench about a foot or a foot and a half over the pipe, and then filling the trench up with water and letting the dirt drop down through the water, keeping the trench full of water all the time.

Mr. L. A. Taylor. I think earth loosely put in the trench will settle much quicker than if it is half or two-thirds rammed. Ordinarily, earth which is put in loosely will go down at the very first rain; of course that depends some on the character of the material too.

Mr. E. A. Taylor. As to the practice of leaving trenches open for two or three weeks, that might do where there is slow progress, as in digging a sewer trench; but in laying water pipe, where you put in perhaps a quarter of a mile a day, you couldn't leave the trench open many weeks; you would have to fill it up.

Mr. Hazard. I agree with Mr. Taylor, that it is better not to tamp at all than to half tamp; but even if you fill the trench up loosely, the traffic will harden the surface so it makes a sort of a bridge by the pounding of the horses and the wheels. If rain doesn't come pretty soon after the trench is filled, it will hold up a long time before it settles. In the case I cited it held up, I think, for four years before it went down at all, and after that it settled for about two years. I think it is about seven or eight years now since the trench was dug, and I noticed the other day a depression of about 4 inches along the whole trench. Of course that wasn't as bad as a settlement which would let down a horse.

The President. Mr. Eglee, can you say something from the contractor's standpoint?

Mr. Eglee. I have found in my experience but one way of back filling a trench and having it stay as it ought to stay. One method adopted in city streets is to thoroughly ram the trench. Now, there is only one way to thoroughly ram a trench and that is not by a rammer the handle of which comes up as high as a man's head, but to use a regular paving rammer, a heavy iron-faced paving rammer; and to use that properly you must spread your earth in layers no more than 3 inches in thickness, and you must have at least one rammer to every shoveller, or three rammers to two shovellers, and the men must shovel slowly. That is one way, but even then it doesn't always stay. After years that will settle down and you will have to replace your paving; but that is the best way of ramming. Any kind of ramming where the man takes the rammer and stands in this way (illustrating) and pounds, is not entirely satisfactory; because the usual method of ramming trenches, where that kind of tool is used, is to put some dirt in the bottom of the trench, and the poor men go in there down low so that the taxpayers don't watch them very closely, and they ram just as little as they can. And when they get up to the top, where the "committee of forty-nine" can see what they are doing, then they begin to ram hard and put a crust on top of the earth, and that is just exactly what you want to avoid. You have got all your soft material underneath, and the water works through under this hard surface and attacks all the loose, soft, half-rammed material, that goes down and then you have a nice crust on top for somebody to fall through some day That is the method of ramming usually employed in suburban towns. I have back filled trenches for fifteen years, and I have never rammed them when I could help it. I always kick.

There is one method, however, of back filling a trench and leaving the trench absolutely right, just one method, and in employing that method the contractor takes the risk; in fact the contractor takes the risk anyway. What does your contract say? It says that this work must be delivered to the water commissioners at the end of six months or one year, and the contractor takes the chances all that time. Now, when I first began to back fill trenches I laid awake nights wondering if anybody was going to get injured. I don't do that any more, because in fifteen years I have never had but one

accident, which cost me $200, and that occurred in a very peculiar way. I built the water works in a certain town and back filled the trenches, and in front of the post office I rammed it thoroughly. Two years afterwards, when visiting some friends in that place, I drove across the trench in front of the post office, and my horse fell in and I had to kill the horse. (Laughter.) That is the only loss in fifteen years. Now, I will tell you what I think is the best method. It is to take a rammer of the character I have mentioned and ram around your pipe under the bottom of it thoroughly, just as well as you possibly can, and have that ramming follow directly on the heels of the caulkers. Just as soon as the caulkers have finished let certain specially picked men, men who will do this work well, who have no foreman standing over them, but who have been selected to do this work because they will do it well, let them follow right behind the caulkers and ram under the pipe thoroughly. Then fill the rest of the trench just as loosely as you can. Have a slight mound, and lengthen that out so that no one will tip over on it. Then after every rain send your men over this trench and loosen the top of it, and don't let it become compacted, but have it loose so that the water will soak into the trench. That is the best way of settling it. After a winter's rains and snows and frosts have gone over that trench, in the spring time you can go over it and smooth it up and it will be all right then. If you throw your earth into the trench and put water on it, soak it, the earth will shrink away from the sides, just as Mr. Beals says. If you ram it, in most soils you can't ram it hard enough but what a good deal of the earth is soluble in the water that will work its way into the trench. Anything that is soluble in water will be carried down into the bottom of the trench and fill up the little cavaties, and the top of it will finally cave in. You can't ram it hard enough to have it right, because after you have rammed it you can turn a hose onto the trench and work it down. There is only one absolutely sure way, and that is to keep the top of your trench soft, take the risk, and then fix it up in the spring.

Mr. Evans. I believe the trench should be filled half the diameter of the pipe and thoroughly rammed, and then above that, if care is taken to fill in horizontal layers, not allowing the laborers to make hills, as I call them, which allow the dirt to run down and become uneven in the trench, I think your settlement will be so

uniform you will have very little difficulty with it, especially if you mound some 4 or 5 inches above the surface where your trench is. I think there should be great care in seeing that the trench is filled uniformly, and not in uneven ridges. I think there is more trouble from unequal settlement than from any other cause, and that is on account of the way the earth is put in. I do not believe, except in much traveled ways, there is any necessity of ramming the trench to the top. Certainly the way it is ordinarily done I don't believe it does much good. I know I have often said, in going along the trench where they were ramming, that I would be willing to put my watch under 4 inches of earth and risk the glass crystal, and I think it would be perfectly safe to do it.

HANDLING AIR IN A TUBE WELL PUMPING PLANT.

BY D. N. TOWER, SUPT., COHASSET, MASS.

[*Read January 12, 1898.*]

This paper is to give a brief description of the Cohasset Water Works and my experience in fighting air leaks in the wells and suction mains of a driven well supply.

Cohasset is a small town on the south shore about twenty miles southeast from Boston; population about 2,450, this number being quite largely increased in the summer by nonresidents who have summer homes there.

The water supply is taken from 64 driven wells, 2-inch diameter, located in the centre of the town. We have a Blake pump of three-quarter million gallons capacity and a reservoir of one and one-half millions, the latter located at an elevation of 160 feet, which gives an average pressure of 60 pounds. There are about 7 miles of cast-iron mains, 36 hydrants, and 288 service pipes, being an excess of 88 service pipes over the total number estimated at the time the works were built. The suction main consists of 478 feet of 10-inch pipe, 676 feet of 8-inch, 459 feet of 6-inch and 289 feet of 4-inch, a total of 1,900 feet of cast-iron, besides the sixty-four 2-inch driven wells amounting to as many feet more, thus giving a total of 3,800 feet of suction pipe.

The wells were driven in two lines about 650 feet in length each, and about 80 feet apart, connected at about the centre, and on this connection is the sand chamber which is 407 feet from the pump. From this sand chamber is a third line extending in one direction only. On these lines the wells were driven about 24 feet apart, and to a depth of between 18 and 38 feet, the first 10 feet through layers of muck, sand and gravelly hardpan, thence through from 8 to 25 feet of clay which overlays a strata of fine gravel about 3 feet in depth, from which the water is taken. Below this gravel is bedrock.

The pump was started December 17, 1886. At that time there

were but few services laid, so there was very little work for the pump. The first year we got along very well, but the next, the number of services increasing and the water in the ground above the clay strata getting low, the joints in the cast-iron suction mains were prevented from being sealed by water, thereby allowing air to reach the lead joints. Then I began to be troubled with air, for as each piston moved towards the water end of the pump, the air that had been drawn in on the previous stroke would be compressed and the piston rod would be seen to jump from half an inch to an inch at nearly every stroke. This was very annoying, and I began to study means of prevention.

As there were 1,900 feet of suction pipe laid from 18 inches to 7 feet deep, and 64 wells that were not gated so that any one or more could be shut off independent of the others, or so that all could be closed to allow a pressure to be had on the mains to assist in locating any imperfect and leaky joints, a difficult problem to solve seemed to be present. I think you will admit that the prospect of finding the leaks was not very encouraging.

Previous to this time I was aided in finding a small leak in the 10-inch line leading from the pump to the sand chamber, and covered but about 18 inches, by a man who was mowing the grass above it. He came to me and said that he heard a funny sound in the ground out in the meadow. "It sounds like a nest of bees," he said, "a sort of whistling noise." I instantly mistrusted the cause, and asked him to show me the spot. He led me to a place over the 10-inch line, where, inside of a circle of about 4 feet diameter, the grass was dry and dead while outside it was fresh and green, caused without doubt by the air being drawn down through the ground and absorbing or evaporating all the moisture.

I set a man to digging, and he soon came to a joint in the pipe. I could very plainly hear the air rushing in and I thought a large leak had been discovered. He brought the calking tools, and as the joint was quite dirty, we washed the lead before calking. In doing so, some of the dirt was drawn into the joint wholly stopping the leak, thus showing how very small it must have been. The joint was thoroughly driven before covering. We then examined all the joints in the line without finding any others defective. We examined the ground over all the suction pipe, hoping to find more dry spots of grass, but found none. I could see that the trouble at the

pump was gradually increasing, and at the sand chamber where the water from the different lines came together, could be heard quite a commotion. My whole thought was how to remedy this trouble. I finally decided, that instead of going to quite an expense in digging to all the joints and connections in the suction pipes, to investigate, with the chances of success very uncertain, as it was quite probable that there might be one or more split couplings in the wells, I would try to overcome the difficulty by removing the air from the pipes before it reached the pump, thinking that in so doing success might be more certain.

With permission from the directors to make my experiments, I had the Blake Manufacturing Co. make a small air pump, $3\frac{1}{2}$x$4\frac{1}{2}$x4, which was placed in the pump house. I cut in a 6 on 10 tee in the 10-inch suction main about 75 feet from the pump house. This was placed looking up, and into it was leaded a piece of 6-inch pipe with a plug in the upper end and a 3-foot water glass on the side. From the top of this pipe was laid a $\frac{3}{4}$-inch pipe to the air pump. I had calculated that the air in the water flowing along in the 10-inch pipe from the sand chamber to the pump would collect in small bubbles and rise to the top of the pipe, and by having a few inches more vacuum on the air pump the air would rise in the chamber and be taken away by the pump. The result was all that could be desired. The air was wholly removed, and the pump would run all day without a kick.

This air pump answered the purpose for about three years, I think, but as the number of services was gradually increasing and more water being needed, its limit of capacity was reached. A larger air pump was then procured and connected to the air chamber with a larger pipe. This answered for a while, but the demand for water constantly increasing, a greater lift was shown by the gauge on the pump. Suddenly, one afternoon, the main pump started up at a speed of about 500 revolutions per minute, more or less, in place of twenty-five, the usual speed. It was evident that some one or more wells of the sixty-four had given out, but which one, and how to find it?

At the sand chamber are three gates dividing the wells into three sections. The next day I had the pump run at the usual speed until near the same amount of water had been pumped as on the day before, as indicated by the register. The engineer was then

asked to stand by the pump so as to be ready to shut down as soon as the air came. I went to the sand chamber and closed one of the gates, cutting off thirty wells, and then went back to the pump house to watch the gauge. As we were then pumping from thirty-four wells, I knew it would soon cause the same trouble as the day before or show more vacuum on the gauge. It was air as before, showing that the trouble was not on the line shut off. We tried the other lines on the following days, the last day being able to pump slowly from forty-three wells with more vacuum on the gauge than formerly. This satisfied me that the trouble was on the last line shut off. We then opened up all the wells on that line and measured the depth of each. I found eight wells that were less than 25 feet deep, one of them being less than twenty. I thought best to disconnect these eight 25-foot wells, which we did, and then all went well. We kept at work and examined about all the wells in the system, but found none that I thought best to disconnect.

Then for a year or more I got along without much trouble, but each year the demand for water increased and there was consequently more air to be taken care of, and soon two air pumps were unable to handle it, some slipping by the tee and so reaching the pump. As one air chamber had proved so effectual, I concluded to put in a second one. This one I put in the pump house so that it could be used in the winter, as I found that with all the ground where the wells are, flooded, as it always is in the winter, there was still some air that needed taking care of. I soon learned, after putting in the second air chamber, that a larger air pump would be required. Such a one was procured, one for business, a 10x8x12.

There has been no trouble since in handling the air to a certain point. I feel quite sure that there is a split coupling on some one of the wells, as I found that we could pump all day by not exceeding 20 inches of vacuum. More than that soon causes trouble.

I often think how an unlimited supply of water from a river or pond would be appreciated, which most of you have. In most cases where there are driven wells there is a pond or river within a short distance, which can filter to the wells, but in my case, there is no sign of good water on the surface of the ground within a mile. I live in hopes of securing an increased supply during this year. Last fall the ground was tested over quite an area, but within reach of the pump. Nineteen trial wells were driven, and we think that by

going about 1,500 feet in another direction we can get considerable more water.

I would say that my way of separating air from water has been greatly improved upon by the use of what is called an "Air Separator," in the shape of a cylinder about 4 feet in diameter and 6 feet high, with a partition in the middle. The separator is set on end near the pump, the top of the partition is on a level with the top of the water cylinder with about 2 feet of space between the top of the partition and the top of the separator, to which the air pipe is attached that connects with the air pump. The suction pipe leading from the wells is connected at the bottom of the separator on one side of the partition, and on the other side, at the bottom, is the connection with the pump. The air pump is intended to raise the water a few inches above the top of the partition, when it flows over in a thin sheet the width of the diameter of the separator, to the other side. The enlarged area of the separator allows time for the air to rise into the space above and be removed by the air pump and the water is drawn to the main pump. This can be seen in operation at Hyde Park, and at Eaton Meadows in the town of Malden.

DISCUSSION.

THE PRESIDENT. Mr. Forbes, you have a driven well system, and perhaps you will say something on this subject.

MR. FORBES. We have no air on the Brookline system. All our wells are more than 35 feet, and I wouldn't have a well unless I could have more than that depth. We have a mile and a half of suction mains, 24-inch, 20-inch, 16-inch, 12-inch and 10-inch, and about 165 wells. We have no air, no air pump, no sand chamber, and nothing of the kind. The whole system is air-tight. We pump at the rate of 5,000,000 gallons in 24 hours while we pump.

MR. TOWER. I would like to ask Mr. Forbes how low the ground water is in the wells in a dry time?

MR. FORBES. It stands 2 or 3 feet below the bottom of the main after we have pumped a few hours, and during the night it generally rises over the main. We have a check valve so the air can't get into the suction; otherwise the probability is the whole main would fill full of air so we couldn't start it. We have no air pump and no sand chamber, and the pipe runs right onto the pump.

Mr. Tower. In a dry time the water in our wells will be 18 feet below the surface of the ground where the wells are driven, and 21 feet below the pump cylinder, and that will be in the morning when we start the pump.

The President. Mr. Evans, will you say something on this subject?

Mr. Evans. I have had no experience with driven wells, but I have seen some up in Lowell. When they started with a driven well system they had a great deal of difficulty. I have watched their engines, and at the end of the stroke they would kick 2 or 3 inches, so you would think the end of the pump cylinder was coming out. They had to put in a large air receiver and an air pump before they could control the air at all. I think their experience was the common one, and Mr. Forbes is certainly very fortunate not to have had that kind of trouble.

PLACING A 10-INCH HIGH SERVICE PIPE ACROSS A RIVER.

BY FREDERICK W. GOW, SUPT., MEDFORD, MASS.

[*Read December 8, 1897.*]

In Medford, as in a number of our New England cities and towns, there are two systems of water supply. The low system, which is supplied by gravity, feeds the central and easterly side of the city, and the high service main passes through the center and feeds the northerly and westerly and southerly sides of the city. Part of the westerly side, being low, about as low as any part we have, is supplied from this main through a reducing valve. In passing from the westerly to the southerly side of the city we were obliged to cross the Mystic river. At the point of crossing it is 130 feet wide and is spanned by a wooden bridge supported by three stone piers. The roadway of the bridge is narrow, and as half of the bridge is in Somerville it was deemed unwise to go over the bridge. The river at this point being pretty well interspersed with a deep bed of mud and quite a collection of large boulders, it made going under the river rather difficult, so we simply did, what had been done a hundred times before, went across the river on the bridge piers.

In doing this we built a staging under the bridge by boring through the planking; boring a set of holes every 10 feet, about 7 feet apart, and putting through the holes inch rods or bolts about 8 feet long, and on the bottom ends of the rods putting pieces of 4x6 which were bored, slipping those over the ends of the rods and then putting on nuts and washers, thus making hangers to carry the staging. Then we put 2-inch planks across on those hangers, and then took down the stone work on the top of the piers in the line of the pipe, going low enough to get the pipe through. We leveled up the piers, and then placed between each set of piers a set of 15-inch steel channel irons, 36 feet long, about 2½ feet apart, tied together every 6 feet with wrought-iron straps 2-inch x ½-inch. Those straps were bolted on either side of the lips of the channel irons. Resting on the lips of the channel irons on the bottom we put bed blocks of 3x10 pine

at each set of straps, and on top of these blocks set 4x6 pine blocks recessed to the curve of the pipe, for the pipe to sit on. Then we took the pipe through from either end, slid the pipe along on rolls on top of the channel irons to their respective places, let them down on the cradles, and put them together in the usual manner. After the pipe had been all put together and tested, a flooring was built under the pipe of two layers of inch boards laid one on top of the other to break joints, simply laid in crosswise on the lips of the channel irons, the 3-inch blocks under the cradles having been rabbeted out on either side so that the second layer of inch boards lapped over onto the 3-inch block, making practically a tight bottom.

After the floor was put in we filled in the whole space around the pipe with charcoal dust packed in tightly, and then by laying stringers lengthwise bolted to the top of each channel iron, we made a roof over the whole structure, nailing $\frac{7}{8}$ matched pine sheathing crosswise, and covering it the same as the bottom, breaking the joints. This made a practically tight box, after which it was painted.

DISCUSSION.

Mr. Whitney. I would like to ask Mr. Gow if he considered any other material for packing the pipe except charcoal?

Mr. Gow. We did not. In fact we were doubtful at first whether to pack it or not, for the main supplies quite a district, and we had very little fear of its freezing anyway on account of the circulation.

Mr. Whitney. How much thickness of packing have you on it?

Mr. Gow. There is a space around the pipe of about 6 inches.

Mr. Bates. I would like to ask Mr. Gow if the box is continuous?

Mr. Gow. The channel irons come within 6 inches of each other, and on the sides we pieced out with boxing. It makes the box continuous. There are four sets of channel irons, and it makes one continuous box the whole length under the bridge.

Mr. Walker. Is there any expansion joint?

Mr. Gow. No, sir.

Mr. Coggeshall. Does the water ever rise in the river to cover the pipe?

Mr. Gow. No, sir, it does not. There is a space of some 5 feet between the box and the river at high water.

Mr. Kimball. I would like to ask if that has been subjected to a winter's freezing?

Mr. Gow. Yes, two winters' freezing.

Mr. Kimball. Why I ask is because of an experience of my own at Putnam, Conn. We had a 6-inch pipe boxed, crossing a small stream, a span of not over 15 feet, and we filled the space with sawdust, (I presume the action would be about the same with charcoal) some water got in there, either through a leaky joint or in some other way, and it froze solid with the usual result. We took it out and replaced about three lengths of pipe. This is on a dead end, where there is very little service. We put the pipe back, built a double box around it with an air space without any packing at all, and it has never bothered us since. So it would seem as though air was a better protection against frost than sawdust, and quite likely better than charcoal.

Mr. Taylor. Speaking of packing pipe, I will say that at New Haven, Conn., there is, or at least there was a very few years ago, a line of 20-inch pipe, 800 feet long, that has no covering whatever to it and it never freezes at all. But of course the circulation is constant and quite regular. At Newport, N. H., the 10-inch main passes across the river over a bridge. We boxed that, having a double box with an air space of about 2 inches without any packing. And my experience has been that where there is any probability of any water from leaks or anything of that kind, it is better not to use sawdust and to have the air space alone; because if there is any little leak it will probably work out, and unless there is considerable thickness of material I believe that air is better than sawdust or charcoal.

Mr. Walker. We are speaking about protection, now, and there has been a good deal of talk in the last few years about protection. We have across the Merrimac river, in about the coldest place in the world, at least in this part of it, an 8-inch pipe without any protection whatever. It hangs right up on the sidewalk of the bridge, and we let the water go through there in the winter time and shut it off from the river crossing, unless in case of a big fire. The pipe is under about 90 pounds pressure and it feeds about 8,000 inhabitants. The expansion joint in the middle went just an inch and a half last winter. It is a wrought-iron pipe 600 feet long.

Mr. Haskell. It is probably true that a pipe without any pro-

tection whatever would not be liable to freeze with the water running through it freely, and that explains why the action of the frost has been so different in different places. There would be no danger where there is a large amount of water running through a pipe, and there would be great danger where there was no water running through a pipe. In regard to the best material to use to protect a pipe, I will say we have used almost everything we could think of, and I consider that an air space is about as valuable as any medium we can use, but ordinary concrete, such as they use for concreting sidewalks, is the best material that there is, and tan bark is the next best.

Mr. Walker. I would like to ask one question. Suppose you had two bridges and you were going across both bridges; say the two bridges were 1,000 feet apart and you had an 8-inch pipe going across both of them. Now, wouldn't one of them freeze if you let them both run?

Mr. Cook. I will say for Mr. Walker's benefit, although this may not exactly meet his case, that we have in Woonsocket, 540 feet of 20-inch pipe on a bridge, and about 1,000 feet up stream we have about 175 feet of 14-inch pipe. The 20-inch pipe is not boxed; the 14-inch is with a double box and air space. The first winter after the 20-inch was put across the 14-inch remained open, and I had no trouble with frost. On neither bridge is there any expansion joint, but I have no trouble from the fact that the pipe is independent from the bridge. The bridge travels but the pipe does not. The pipe is fitted on rollers.

Mr. Hyde. In Newton, where we have to cross the Boston & Albany subway in a good many cases over the bridges, we use small cuttings of leather to pack with. I got my cue from Mr. Morse, of Natick. He has used them for a number of years, and he tells me that in the coldest weather when they uncover a box it feels warm in the packing around the pipe. No doubt this is caused by the oil in the leather which, perhaps, creates heat, and keeps the pipe from freezing. Now, at night the circulation across these bridges is very small, and some of our pipes are as small as 6-inch. This will be our first winter's experience, but I think there is no doubt the packing will work all right, although we haven't as much space around the pipes as Mr. Gow speaks of.

Mr. Hammatt. Speaking of packing around pipes over bridges,

if I remember rightly, at the time the Lewiston, Me., works were put in in 1878 or 1879, they had two or three canal crossings. The pipes were carried across on independent bridges, made on purpose to support the pipes. As I recollect it they were first put in a wooden box which was filled with tan bark, and the first winter one or more of those lines caused considerable trouble, and one of the bridges gave way. When they came to investigate the matter they found that there had been some leakage, probably from a joint, the pipe was laid the usual depth through the street, and came up with a quarter turn, and made another quarter turn to go across the bridge. In making those sharp turns there probably was some motion in the joints which caused leaks. The box filled with water and froze solid, and it made so much weight that the bridge gave way. If I recall the matter rightly I was told that the next year they abandoned the packing and used simply an air space, and have had no trouble since. At Gardiner I know we had a crossing over the stream, and we used simply an air space there, although there may have been some tan bark used; Mr. Maxey can tell about that.

Mr. Maxey. We used tan bark and it froze and burst, and then we used simply an air space.

Mr. Cook. We all know that pipes filled with water on certain days in the spring and fall will sweat, you have undoubtedly all seen that, and I don't know of any material that can be used to pack around the pipes but what will absorb that moisture.

Mr. Fuller. We had trouble when the Wellesley works were first built. We filled the box with tan bark, and the first winter the pipes froze up and burst. I have no doubt as to the force of Mr. Cook's suggestion, that even if the pipes do not leak there is more or less condensation, and the tan bark or any other material that is put around the pipes will become moist and freeze. I think in regard to pipes that are exposed it will make a great difference what the supply is, whether it is a ground water supply, where the temperature of the water would be nearly uniform the year round, or whether it is a surface water supply where there is a good deal of difference in the temperature.

Mr. Hastings. In Cambridge we have had a little experience with packing pipes. We have a place there where two pipes cross the railroad, a 6-inch and an 8-inch. Both those pipes were packed

with wool waste. That was some six or eight years ago, and we have never had any trouble since. There is very little consumption in the night, and very slow circulation of the water. I think the wool waste works perfectly. This fall the bridge was taken down and I found the wool waste was intact, it didn't seem to have corroded at all. The idea had been that the wool waste would set up a species of spontaneous combustion and would thus keep the pipe warm, but I do not think that had taken place, as the wool waste seemed to be sound and good. But it served the purpose of an excellent packing for a rather small pipe.

Mr. Cotton. I have used lampblack and air space and hair felt to cover pipes with, and as they have all worked well I really don't know which is the best. For the last four or five years I have been using hair felt and an air space in single boxes, one or two thicknesses, according to circumstances, about three-quarters of an inch of the hair felt wrapped around the pipe and wired or fastened on with cords. It is very convenient to put on, very cheap, and I have never had any pipe freeze, although I have had some in places where there was a very small consumption. I think, although it is probable some moisture collects in it, it evaporates more or less. At any rate I still continue to use it and it has thus far served a very good purpose.

Mr. Maxey. Down in the town of Caribou, Maine, where the thermometer goes to 40 degrees below zero, they have a system of water works where they have a pipe crossing the river, I think it is only a 6-inch pipe. The river is 140 feet wide and the consumption on the further side is not very great. They had it at first boxed in the ordinary way and filled with tan bark, and it froze up solid. Then they practically built a small house across the river and put a stove in it, and were actually obliged to run the stove all the time. (Laughter.)

Mr. Gilbert. I have never had any experience in laying large pipes across rivers, but I had four hydrants which were set for fire purposes near a large factory, and it was very low ground, where the water came clear to the top of the ground all the time. The water of course would work through the drip of those hydrants and fill them up and remain so, and we found that the first winter after they were put in they froze up solid, and they kept frozen nearly all winter in spite of all we could do. The next season we plugged up

the drips in the hydrants, but the water got in there in some way and they froze up again. The next season we built some little houses of matched boards over each one of them, and we have had no further trouble with them at all. You can open the doors of those houses any time, and in the coldest weather in the winter the ground will hardly be frozen around the hydrants. You can use them with perfect safety in the coldest weather in the winter. We have some nine or ten private hydrants in the town around the factories, and the same kind of little houses have been built over them, and I have found just the same result when I have examined them, that the dirt is hardly frozen around the hydrant even in the very coldest weather.

Now, one thing more. I had a service pipe which was put in along a bank, the bank was some 6 or 7 feet high, and this service pipe was put in there 6 feet from the outside of the bank and about 4½ feet deep. It was put in quite late in the fall, and just as soon as the coldest weather came on I had a notification from the gentleman owning the premises that he couldn't get any water. I examined it and found it was frozen up. We dug the pipe up, thawed it out and lowered it nearly a foot and filled it in again. But it was only a few days before it froze up solid again and remained so all winter. I hardly knew what to make of it. After talking with some gentlemen who had had a similar experience, I began to think it was on account of its being so near the side of that bank. Well, the next fall I dug that service up, and put a 2-inch pipe over it the whole length, and I have never had any trouble with it since.

Now I suppose all of you have had some experience in putting in services sometimes where there is no cellar under the building, and we all know it is a very difficult matter in cold places to keep them from freezing. I am always particular in such a place to put the pipe through a larger pipe, and I have hardly ever had any trouble from one of those services since we commenced doing it in that way.

Mr. Stacey. I remember some time ago we had a discussion on the protection of water pipes by various substances, when our venerable friend and brother, Mr. Jones used to meet with us, and his opinion was asked as to the best substance to cover a pipe with to keep it from freezing. He mentioned a number of things he had used, but finally said that according to his experience there were

only two ways to keep pipes from freezing when exposed to the frost, and those were either to let the water run, or to keep the water out of the pipe. Well, perhaps that was a pretty broad statement, but the covering I think depends somewhat upon the condition and the locality in which the pipe is situated. If there is a circulation, it is natural to suppose that the water in passing through the pipe is not exposed to the cold long enough to be reduced to the temperature of freezing; that is, it comes at above freezing from the ground to the point where it enters the pipe crossing and is exposed, and before it has a chance to cool to the freezing point it has passed on its way below the frost again.

Now it seems to me that any fibrous packing that can be put around the pipe, where there is moisture, does not give it much protection. If a pipe lies on a ledge, even if it is below the frost line, the frost will follow the rock down to a considerably greater depth under certain circumstances than it would if the pipe was laid in the earth. So it looks to me that if you are going to cover a pipe with anything at all you want something that is impervious to water, if you can get it.

I have a standpipe set up on a trestle, with a 12-inch pipe leading up to it, 60 feet high. It stands in about as exposed a place as can be found in this section of the country. We protected that pipe by putting sheathing around it, we put a 6-inch air space between that and the pipe, being careful to keep the sheathing away from the pipe so that any moisture on the pipe would run down to the bottom without communicating with the sheathing in any way. Outside of that first sheathing was put an inch of hair felt, held on with brass bands. Then there was a 4-inch air space outside of that, and another sheathing of matched boards, narrow strips. We keep the water in circulation; this is used for fire purposes only, and of course in the winter it would remain practically stationary, and the water would freeze over on the top quite solid and tight; to prevent that we keep enough circulation in the pipe to keep the ice moving. We have used this for two years and haven't had any trouble with it and I don't expect to have any.

I have had some experience with pipes in wet places. On one side of Main street I have a service pipe entering a house, not over 12 inches below the sidewalk, on a ledge. I couldn't sink it any lower without blowing the house up, and if I blew the house up they

wouldn't want the service pipe, so I had to put it in as I did. I packed that solid with tar concrete. I have two other services covered with concrete which have been in eight or nine years, going up a bank where there was a ledge with 2 feet of covering. When the concrete is made, I am particular to have it made pretty rich with tar having considerable pitch with it so it will soon set and stay in place; and then I want it thoroughly rammed and compacted to exclude any moisture from getting into it. In a wet trench you have got to be pretty careful not to get any water mixed up with the concrete in putting it in.

I am going to try the experiment on a 16-inch pipe which I have to lower in a kind of siphon to cross under a subway. We are going to lower the pipe and I propose to lay it in concrete. The only thing I shall have to contend with will be the amount of water, but I am satisfied I can protect it if I can keep the water out until I get the concrete in.

In regard to the protecting of hydrants, the gentleman says he has some where the water comes up near the surface. I have two or three where the water will run out of the nozzle from the drip, and building a house over them wouldn't do any good, I have about a dozen hydrants where the drips are plugged, and I would say frankly I wouldn't give a continental for a drip on any hydrant in the winter. I pump every one. We plug the drip, find the hydrant is tight and pump it out, and then we haven't anything to think of, unless somebody bothers with the gate after we once find it tight. I think from what experience I have had that concrete properly mixed and properly compacted around the pipe, and protected on the ends so that the moisture or water can't get in and work down around the pipe, (and I think that is a very important thing,) is the best material I know of to protect a pipe, and it will last forever almost. But no matter how well the pipe is protected, if it freezes on the end it will freeze right down through the pipe. I have had a pipe freeze in the cellar and out to within two feet of the main, some 20 feet. When we dug down beyond the cellar wall, to be sure we were right about the matter, we didn't find any frost back of the cellar wall for 2 feet, but we had to thaw it out to within two or three feet of the main before we struck water. So no matter how well we cover a pipe, if it is exposed at the ends to the frost it will freeze down through the covering. That has been my experience.

PROCEEDINGS.

QUARTERLY MEETING.

Young's Hotel,
Boston, December 8, 1897.

President Kent was in the chair, and the following members were present:

Active Members.

Everett L. Abbott, Charles H. Baldwin, Lewis M. Bancroft, Frank A. Barbour, R. S. Bartlett, George E. Batchelder, Oren B. Bates, Joseph E. Beals, James F. Bigelow, George Bowers, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, G. L. Chapin, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, John W. Ellis, J. H. Fairbanks, B. R. Felton, F. F. Forbes, Frank L. Fuller, Julius C. Gilbert, T. C. Gleason, Albert S. Glover, W. J. Goldthwait, J. A. Gould, Frederick W. Gow, E. H. Gowing, Richard A. Hale, E. A. W. Hammatt, John C. Haskell, L. M. Hastings, V. C. Hastings, Horace G. Holden, H. N. Hyde, Willard Kent, Patrick Kieran, Frank C. Kimball, James W. Locke, C. M. Lunt, J. S. Maxey, Frank E. Merrill, Leonard Metcalf, James W. Morse, Thomas Naylor, Frank L. Northrop, John H. Perkins, W. H. Richards, W. W. Robertson, William Ryle, A. H. Salisbury, J. W. Smith, George A. Stacy, Edwin A. Taylor, L. A. Taylor, Robert J. Thomas, Wm. H. Thomas, D. N. Tower, W. H. Vaughan, Charles K. Walker, J. Alfred Welch, John C. Whitney.

Associate Members.

M. J. Drummond, by Wm. V. Briggs.
Deane Steam Pump Company, by F. H. Hayes.
Hersey Manufacturing Company, by J. A. Tilden.
Ludlow Valve Manufacturing Company, by H. F. Gould.
Jenks, Henry F., Pawtucket, R. I.
Lead Lined Pipe Company, by T. E. Dwyer.
Neptune Meter Company, by H. H. Kinsey.
Perrin, Seamans & Company, by H. L. Bond.
Rensselaer Manufacturing Company, by Fred S. Bates.
Robertson, R. A., Providence, R. I.
Smith, Anthony P., Newark, N. J., by Mr. Van Winkle.
Smith, Benjamin C., New York City, N. Y., by F. A. Smith.
Smith, B. F. & Bro., by B. F. Smith and James Martin.
Sumner & Goodwin Co., by F. D. Sumner.
Union Water Meter Company, by J. P. K. Otis and Mr. Northrop.
Wood, R. D. & Co., by Jesse Garrett.

GUESTS.

William W. Wade, Woburn, Mass.; Mr. Doyle, Wakefield, Mass.; J. F. Monehan, Lowell, Mass.; H. L. Thomas, Hingham, Mass.; and J. W. Milne, Fall River, Mass.

The Secretary read the names of the following list of applications for membership:

RESIDENT ACTIVE.

William W. Wade, Water Registrar, Woburn, Mass.

Francis E. Appleton, Paymaster of Locks and Canals Company, Lowell, Mass.

Frederick S. Hollis, Biologist, Boston Water Works.

NONRESIDENT ACTIVE.

Edward Phillips, Chief Engineer, Hydraulic Construction Company, New York.

John Caulfield, Secretary Water Company, St. Paul, Minn.

C. O. Probst, Secretary State Board of Health, Columbus, Ohio.

Francis C. Green, Engineer, New York.

On motion of Mr. Fuller, the Secretary was instructed to cast the ballot of the Association for the candidates, and they were declared elected members of this Association.

Lucian A. Taylor read a paper entitled, "Construction of the Water Works, at Newport, N. H." Messrs. Haskell, Fuller, Holden, Walker, Cook, Coffin and Metcalf took part in the discussion.

Frederick W. Gow, Superintendent, Medford, Mass., described the placing of a 10-inch high service main across the Mystic River. The discussion which followed was participated in by Mr. Bates, Mr. Kimball, Mr. L. A. Taylor, Mr. Walker, Mr. Haskell, Mr. Hyde, Mr. Hammatt, Mr. Cook, Mr. Fuller, Mr. Hastings, Mr. Cotton, Mr. Maxey, Mr. Gilbert and Mr. Stacey.

Mr. E. A. W. Hammatt, of Boston, read a paper on "Back Filling Trenches." The subject was discussed by Messrs. Hyde, Haskell, Winslow, Gilbert, Fuller, Fairbanks and Taylor.

Adjourned.

ADJOURNED MEETING.

Young's Hotel,
Boston, Jan. 12, 1898.

President Kent in the chair.

The following members and guests were present:

Active Members.

Solon M. Allis, Francis E. Appleton, Charles H. Baldwin, Lewis M. Bancroft, George E. Batchelder, Oren B. Bates, Joseph E. Beals, James F. Bigelow, John T. Cavanagh, George F. Chace, Charles E. Chandler, G. L. Chapin, Harry W. Clark, William F. Codd, Freeman C. Coffin, H. W. Conant, Byron I. Cook, Henry A. Cook, Eben R. Dyer, Charles H. Eglee, George E. Evans, J. H. Fairbanks, F. F. Forbes, Frank L. Fuller, D. H. Gilderson, Albert S. Glover, W. J. Goldthwait, Frederick W. Gow, E. H. Gowing, Francis C. Green, Frank E. Hall, E. A. W. Hammatt, John C. Haskell, L. M. Hastings, V. C. Hastings, William E. Hawks, T. G. Hazard, Jr., James H. Higgins, Frank W. Hodgdon, Horace G. Holden, Willard Kent, George A. Kimball, Wilbur F. Learned, James W. Locke, Thomas Naylor, Edward Phillips, C. A. Probst, W. H. Richards, George J. Ries, Henry W. Rogers, George A. Stacy, F. A. Snow, Edwin A. Taylor, L. A. Taylor, William H. Thomas, D. N. Tower, Charles K. Walker, William W. Wade, John C. Whitney, George E. Winslow.

Associate Members.

Chapman Valve Manufacturing Company, by E. L. Ross.
Coffin Valve Company, by Mr. Weston.
Deane Steam Pump Company, by F. H. Hayes and C. P. Deane.
Drummond, M. J., New York City, N. Y., by Wm. V. Briggs.
Garlock Packing Company, by Mr. Perkins.
Hersey Manufacturing Company, by Albert S. Glover.
Jenks, Henry F., Pawtucket, R. I.
National Meter Company, by Mr. Lufkin.
Neptune Meter Company, by H. H. Kin
Perrin, Seamans & Company, by H. L. Bond.
Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Ross Valve Company, by E. L. Ross and S. R. Stanley.
Smith Benjamin C., New York City, N. Y.
Sumner & Goodwin Company, by F. D. Sumner.
Thomson Meter Company, by S. D. Higley.
Union Water Meter Company, by J. P. K. Otis.
Wood, R. D. & Company, by Jesse Garrett.

GUESTS.

W. E. Hassam, C. E., Worcester, Mass.; A. A. Blossom, Salem, Mass.; J. F. Gleason, Quincy, Mass.; John Gardner, Taunton, Mass.; H. Phipps, Boston, Mass.; J. Taylor, Weymouth, Mass.; H. L. Thomas, Lowell, Mass., and J. S. Beal, Lowell, Mass.

Henry L. Davis, Superintendent of Water Works, Wallingford, Conn., was elected a resident active member, and George A. Soper, Civil Engineer, now connected with the Western Division of the Boston Water Works, was elected a nonresident active member.

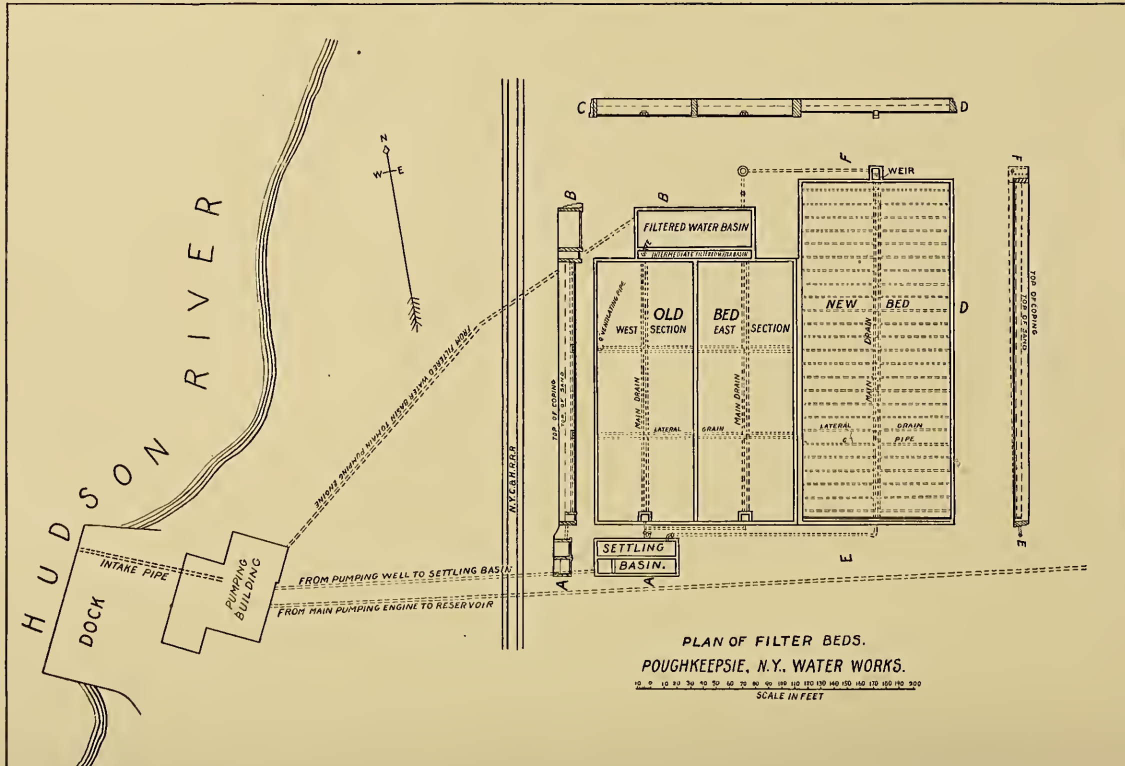
On motion of Mr. Fuller the thanks of the Association were extended to Mr. Forbes for his courtesies extended to the members of the Association on their visit to the new Brookline public bath.

Mr. W. E. Hassam read a paper giving a description of the Worcester distributing reservoir.

Mr. E. H. Gowing read a paper entitled "Back Filling Trenches from Another Standpoint." The paper was discussed by Messrs. Fuller, Beals, Hammatt, Chace, L. Taylor, E. A. Taylor, Haskell, Richards, Hazard, Eglee and Evans.

Mr. D. N. Tower, Superintendent of the Cohasset Works, read a paper on "Handling Air in a Tube Well Pumping Plant."

Adjourned.



PLAN OF FILTER BEDS.

POUGHKEEPSIE, N.Y., WATER WORKS.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE OPERATION OF A SLOW SAND FILTER.

BY CHARLES E. FOWLER, SUPERINTENDENT AND ENGINEER OF PUBLIC WORKS, POUGHKEEPSIE, N. Y.

[*Read March 9, 1898.*]

Mr. President and Members of the New England Water Works Association: Having been honored with a request to present before you a paper on the "Operation of a Sand Filter" I will endeavor to comply by narrating some of the experiences met in the effort, during the past seventeen years, to render the water of a sewage polluted river fit for domestic use by means of such an appliance.

The sand filter of my experience is located at Poughkeepsie, N. Y., a city of about 23,000 inhabitants, situated on the east bank of the Hudson River, about midway between its mouth and the head of navigation.

The construction of its system of water works was commenced in 1869 and completed in 1872. The commission entrusted with the work investigated every probable source of supply and arrived at the conclusion, which subsequent years have fully justified, that the Hudson River afforded the only assurance of an ample volume within the limits of reasonable cost. Their consulting engineer was the late James P. Kirkwood, of Brooklyn, N. Y., who had but recently investigated the filtration systems of Europe in the interest of the city of St. Louis, Mo. The city of St. Louis did not adopt the filtration system, but it was applied to the water supply of Poughkeepsie under Mr. Kirkwood's supervision and in accordance with his plans.

The Hudson River, at Poughkeepsie, has a drainage area of about 11,500 square miles. Within this area is a total population of about 1,000,000 and an urban population of about 500,000. Fifteen miles above Poughkeepsie, on the west shore, is the city of Kingston containing about 23,000 inhabitants. Forty miles above, on the east shore, is the city of Hudson, containing about 10,000 inhabitants. Seventy miles above, on the west shore, is the city of Albany with about 96,000 inhabitants and, above Albany, a total urban population of about 300,000. A short distance above Poughkeepsie, on the same side of the river, is located one of the New York State Hospitals for the Insane. The patients and attendants make a population of about 1,500 or upwards. The institution is completely sewered and the outfall is in the Hudson River 2,797 feet above the intake of the Poughkeepsie water works. The ebb tidal currents flow directly from this outfall past the intake. The central sewer outfall of the Poughkeepsie system discharges into the river 6,124 feet south of the water works intake, and the flood tidal currents, from the outfall, pass far above the intake but nearer the center of the river. The width of the river at the water works intake is about 2,400 feet with a nearly uniform depth of 50 feet, the shores being quite bold.

The pumping plant is located at the edge of the river. The filtration plant, as originally constructed, is located about 500 feet easterly and about 28 feet above mean high water in the river. This plant consists of a settling basin 25 feet by 60 feet in plan and 12 feet deep. The bed is 200 feet long by 150 feet wide, divided longitudinally into two sections by a wall in the center. The walls are vertical, of rubble masonry, and 12 feet in height from coping to top of concrete bottom.

The filtering materials occupy one half the depth, comprising, beginning at the bottom, 24 inches of coarse broken stones, 6 inches two-inch gravel, 6 inches one-inch gravel, 6 inches one-half-inch gravel, 6 inches one-quarter-inch gravel and 24 inches of sand. A main drain, of dry rubble 2 feet by 2 feet in cross section, extends longitudinally through the center of each section and two lateral drains of same dimensions traverse each section at right angles to the main drain.

A gate is placed at the outlet of each main drain, opening into an intermediate chamber 6 feet wide by 88 feet long and 16 feet deep,

from which the filtered water passes, over a weir, into a filtered water basin 88 feet long by 28 feet wide and 17 feet deep. From this basin the filtered water passes to the main pumping engine and thence to the distributing reservoir.

The distributing reservoir has a capacity of 12,000,000 gallons or a practical maximum supply of seven days.

The filter bed was put in operation in 1872. In 1874 an attempt was made to substitute subsidence in the distributing reservoir for filtration and the annual report for that year states that "The use of these beds has been abandoned except as may be occasionally required, when from the stage of the river the water may be unusually turbid." In the year 1875 the bed was in use about six months. In the year 1876 the annual report states they "Were in almost constant use." In the report for 1877 it is stated "The entire supply for this year was filtered." In the report for 1878 the volume filtered is the entire volume pumped, and it is added "The consumers accustomed to drink filtered water will accept nothing else, nor will they consider any circumstance, or complication of circumstances as offering any excuse for their nonuse." In the report for 1879 and 1880 the volumes filtered are the entire volumes pumped. The attempt to abandon the filter bed was not successful.

When I assumed charge of the works, in January, 1881, I found the bed not in use owing to a heavy coating of ice which rendered cleaning difficult. I at once caused the ice to be removed and the bed cleaned and put in operation. From that day I have not at any time seen the water of the river, judging from appearance alone, in fit condition for domestic use without some effort at purification. At that time bacteriological examinations of water supplies were unknown and but few chemical examinations had been made of the Poughkeepsie water; nevertheless I was impressed with the belief that that filter bed, in its best possible condition, was essential to the satisfactory quality of the water supplied to the city and upon that principle have based all action relative thereto, and have allowed no water to be supplied to the city without passing through it.

From various causes the river water has been much more heavily charged with mud and silt at all seasons, during the past eight or ten years, than previously. The normal rate of filtration, that is,

the water pumped from the clear water basin, prior to 1893, was 4,500,000 gallons per acre per twenty-four hours. Since 1893 the rate has been 5,000,000 gallons, or over, per twenty-four hours, per acre. The head, or difference of level between the surface of the water on the bed and that in the intermediate filtered water chamber, required to obtain this rate varied according to conditions, from 1 foot to 6 feet and, in extreme cases, it has increased to 7 feet or even 8 feet or more. During the last six or eight years the endeavor has been to make 4 feet the maximum.

The word ''conditions'' has a very broad significance to one who has been obliged to meet them. To understand this it must be borne in mind that there was on the one hand, among the consumers of water, a lingering impression, occasionally expressed, that the filter was not in use, and, on the other hand, my firm conviction that the constant use of the filter was a sanitary necessity and a firm determination that no unfiltered water should be pumped to the city.

A feature of this bed was a set of six 6-inch cast iron pipes, in each section, one being set vertically over each end of the main drain and the outer end of each lateral. They were open at each end and extended from the top of the drain nearly to the top of the side walls. The purpose of these pipes, evidently, was to provide an exit for the air in the lower portion of the bed when it was being filled by water flowing on the top and thereby prevent disturbance of the sand. I discovered after a time, however, that a practical use was made of them not altogether intended by the designer. I noticed that after reaching nearly the limit of head the bed would sometimes seem to run for a disproportionate time without material increase.

Upon examination and inquiry I found that the night engineer, and not infrequently the day engineer, would, in order to delay the cleaning of the bed, allow the water to rise and overflow these ventilators thus admitting an appreciable volume of unfiltered water to the drains below and relieving the bed. This practice was prohibited at once and a close watch maintained to prevent its recurrence.

During the years 1881 to 1883 the water of the river was much clearer than I have seen it since and, consequently, the work of the bed was less. It was the practice to ''clean'' the bed by removing from the surface of the sand the silt left by the water in passing

through. This was done whenever the bed failed to pass enough water under the given limit of head. The work was done by men with square pointed shovels who "skimmed" the slimy coat from the sand and deposited it in wheelbarrows which were wheeled by other men and deposited at the side of the bed. Still other men threw the deposit to the bank above. When the bed was new this was sufficient, but when I assumed charge it was not sufficient and it was the practice, after skimming, to loosen the sand with garden forks and then rake the surface over. This would not be done at every cleaning, but it soon became necessary to do it at every cleaning; and, after a time, even this was insufficient to enable the water to pass through readily but it would require from twelve hours to forty-eight hours after cleaning, for the bed to deliver the normal rate. In the construction of this bed no provision was made for drawing the water from above the surface of the sand when it became necessary to clean it. It was necessary, therefore, for the water to filter through before the work of cleaning could be commenced. In 1885 the condition of the filtering material had become such that forty-eight hours were required, after pumping ceased, to drain the sand so that cleaning could begin.

Prior to this time it had been the practice to replace the sand on the bed when a depth of about 6 inches had been removed in cleaning. Once only a depth of 10 inches had been removed. Below this depth the filtering material had not been disturbed since construction. Under the conditions mentioned it will be observed that a period of five days would be required from the time pumping on the bed ceased, in order to prepare for cleaning, to the time of obtaining normal flow from the bed after cleaning, namely, two days for draining, one day for cleaning and two days for obtaining normal flow.

At such a time if a storm, lasting two or three days, should occur to prevent cleaning the effect will be readily understood.

On the fourth day of January, 1886, a severe storm occurred as the bed was being cleaned and stopped the work when about two-thirds done. The rain was succeded by a muddy state of the river water previously unknown. In addition to this a period of severe cold set in which caused a large increase of consumption amounting in some days to nine-tenths of the full capacity of the pumping engine. The bed was filled to the coping and forced to its utmost,

but was unable to filter the full amount of daily consumption and the balance overflowed through the ventilating pipes, before mentioned, unfiltered, rendering the water delivered to the city very roily and causing great complaint. By constant pumping it required nearly three weeks to store sufficient water in the reservoir to permit the pumps to stop long enough to clean the bed and, when it was again cleaned its efficiency was but little improved. The sand pores had become so filled as to render it, under the water pressure necessary, like a mass of compact loam and almost as impervious to water. It thus became necessary, at once, either to remove the sand entirely and replace it with new, or after removing the old sand to wash and replace it. The latter course was decided upon and, accordingly, the entire body of sand was removed, to the gravel, and washed and replaced. The work was commenced in the latter part of March and completed the latter part of October, the bed being in continuous use meanwhile. A thickness of from 1 inch to 2 inches of sand was removed at a time and washed and placed in a pile. Then another, equal thickness, and so on. When the sand had been removed to within about 3 inches of the gravel the east section of the bed was shut off, the remainder of the sand removed from it, and washed, and the full depth of the washed sand replaced on this section.

During this time all the water pumped to the city was filtered through the west section. The west section was then shut off and the process repeated there. When the work of replacing was completed on both sections the bed was, apparently, in as good condition as a new bed. From this time the sand removed in cleaning, and washed, was not replaced as frequently as heretofore.

No sand was replaced until 1890 when, the sand remaining on the bed, about 6 inches in depth, was removed and washed and all was replaced as before. In 1893 the sand removed and washed during the previous three years was replaced on the bed together with about 400 cubic yards of new sand. In 1894 about 300 cubic yards of new sand was added and about the same quantity of old sand replaced making a depth of about 7 inches. In 1897 all of the sand on the bed was removed and wasted and new sand to the depth of 30 inches put on the bed.

One of the worst experiences occurred during the month of April, 1895. A heavy rain, on the 8th and 9th, brought down a charge of red mud and silt which stopped filtration. The pumps

were stopped on Thursday morning, the 11th, with nearly 14 feet of water in the reservoir. Allowing forty-eight hours for draining the bed we expected to clean on Saturday. On Saturday, however, it rained heavily; also a part of Sunday, so that no cleaning could be done until Monday, the 15th; but, even then, the bed was not sufficiently drained, owing to the rains of Saturday and Sunday. A force of men was put on and urged to their utmost and the bed cleaned and pumping to the reservoir started at seven o'clock in the evening, with less than 4 feet in the reservoir. Since it is impracticable to draw from the reservoir below 3 feet we had but 1 foot available, or twelve hours supply, when pumping began. The river being still very muddy we were compelled to stop pumping on Saturday morning, the 20th, after running four and one-half days. The bed was cleaned on Monday, the 22nd, and pumping began with less than 3 feet available in the reservoir. We were again obliged to stop on Saturday morning, the 27th, after running four and one-half days and clean on Monday, the 29th, starting the pumps with less than 3 feet available in the reservoir, so that three times during that month, we were in such condition that a rain storm of twenty-four hours would have compelled us to pump unfiltered water. We were obliged to clean the bed again on the 6th of May, making four times in five successive weeks, an experience unequaled before or since.

One of the great hindrances to the operation of this bed has been the growth of a species of green, filamentous, algæ on the surface of the sand. It does not develop in every year nor at the same time in the year. It sometimes begins in the latter part of May and sometimes not until September. It usually disappears with heavy frost. Its development begins in small round patches on the surface of the sand and continues with greater or less rapidity, according to temperature and condition of the water, until the entire surface is covered as with a blanket and the passage of water is entirely stopped. It has been known to develop on the clean sand and entirely stop filtration within seven days from cleaning. An essential condition for its rapid growth is clear sunlight. It will not develop in the dark and very little in the shadow of any object. All the basins, as constructed, were open to the sunlight. Much trouble was experienced from the growth of the same species of algæ in the clear water basin. In 1891 this basin was covered so as to exclude the light and no trace of algæ has been seen in it since. When filtration

is stopped from this cause there is no alternative but to drain the bed and clean in the usual way. The algæ cannot be removed under water. When the bed is drained and the algæ is allowed to dry it will cohere and roll up like a piece of paper. But touched with a shovel or other appliance for its removal, under water, it instantly flies in all directions in minute particles which immediately settle upon the sand and commence development vigorously on their own account. It has sometimes happened that the delivery of the bed has commenced to decrease, from algæ growth, within forty-eight hours after its removal. These extreme cases are, however, of rare occurrence. As this development always occurs during one of the seasons of greatest consumption of water it has sometimes taxed us to the utmost to maintain the supply of filtered water. I have never observed that its presence imparted either odor or taste to the filtered water.

During the last eight or ten years the frosts of winter have greatly hindered the maintenance of the bed in proper working condition. As before mentioned the river water has been much more turbid during this later period and it has seemed much more difficult to catch a thaw at the right time, and of sufficient duration, to enable the bed to be properly cleaned. In order to clean in the winter the first operation is to remove the ice. This will vary from 10 to 20 inches in thickness and we have removed some 28 inches thick, though that thickness is very seldom attained and then does not extend over the entire surface. In removing the ice the bed is filled to the coping, and the ice cut in pieces and hauled out by men. The operation requires about a week, more or less, depending upon the thickness of ice and the number of men employed. When the ice has been removed, pumping is stopped and the bed drained. If we have struck a favorable thaw, and, if during the forty-eight hours or more required to drain the bed no frost occurs and none occurs until the bed is cleaned, all is well and the bed will probably be in good order. It, however, more frequently occurs that 2 or 3 inches of ice forms while the bed is being drained.

We have sometimes removed the ice and drained the bed without frost, and early in the morning of the day of cleaning, a sudden drop in temperature occur that would freeze the sand and stop the work before it was completed. It sometimes happens that we are unable to foresee the failure of the bed in time to remove the ice owing to a sudden change in the character of the river water. In

such cases an effort is made to clean by lowering the ice on the sand, breaking it up, turning over the pieces and cleaning underneath. This is very unsatisfactory and only undertaken in emergencies. A sudden drop of temperature will sometimes stop even this operation before it is completed. In February, 1893, the bed suddenly failed with about 10 or 12 inches of ice on the surface and low water in the reservoir. It was impossible to continue and the bed was drained and the ice lowered to the sand. As much ice as possible was removed from one section while the bed was being drained. The work of cleaning was commenced, but before two-thirds of the section from which the ice had been removed, had been cleaned, the sand froze to such an extent that the work was stopped. There were but 5 feet of water in the reservoir and I decided to turn on the water and get what we could from the bed, fully expecting to be compelled to pump direct from the river within the next twenty-four hours. To my surprise, on going to the bed the next morning, I found it delivering its normal flow. The ice, on the section from which none had been removed, had settled evenly upon the sand and the severe cold had frozen the sand to the under side so that when the ice arose with the inflowing water it carried about one inch of sand from the entire surface of that section with it. It is not a method of cleaning to be recommended but it delivered us at the only time in my experience that the elements were in complete mastery. It is very rare, however, that all the conditions would be favorable to such action.

The under surface of the ice must be even, the surface of the sand even, the thickness of the ice sufficient to lift the sand and not enough to protect the sand from cold and the cold intense enough to freeze the sand under the ice. All of these conditions must occur together, which is very seldom the case.

In cleaning the bed, as before described, from one-quarter inch to one-half inch of sand was removed under normal conditions. In cases of frost the depth would be increased, sometimes to 2 inches or more. The labor required, under normal conditions, was one man for each 150 square feet of surface cleaned per hour, including wheeling and elevating to bank. As the sand is in use it becomes, in time, coated with a gelatinous film, throughout its depth. The finer silt also extends, in continually decreasing quantity, for a considerable depth below that removed by cleaning. The pressure to maintain a given flow, with the surface clean, gradually in

creases. Consequently, the pressure throughout increases, until, after a sufficient time, the water will not pass through even after cleaning and it becomes necessary to loosen the sand. This is done by the use of garden forks, as before mentioned, which are pressed into the sand a sufficient depth, vertically, and the top of the handle drawn backward sufficiently to loosen the sand in front of it.

At first the forks need enter but 3 or 4 inches but the necessary depth gradually increases until the full length of the fork is used and even this is not sufficient and the entire body of sand must be removed and washed or renewed as was the case in 1886. After the sand is loosened the surface is raked over evenly with a garden rake. Forking and raking requires about one man to each 500 square feet of surface per hour.

Under the foregoing conditions of sand and pressure, the sand will sometimes become so compact and hard that a considerable force is required to press the fork into it, and the tramping of men on the surface makes no impression. The time required for a filter to attain the condition referred to as occurring in 1886 would, of course, depend upon the rate of filtration and the character of the applied water. The period of constant use had been about ten years previous to 1886. Subsequent to that the sand was all removed and replaced at the end of four years, in 1890, before such condition had attained. Subsequent to that the entire body was not removed until 1897, a period of seven years, when the same conditions occurred and it would have been impossible to complete the year. The most favorable conditions for cleaning are fair, mild weather, not cold or hot, with the sand slightly moist. In the heat of summer, under a glaring sun, the sand sometimes becomes baked to a depth of nearly an inch compelling the removal of a depth greater than would be necessary, were this not the case, thus increasing the expense. Greater care is required in cleaning as the bed grows older. The shovels should be lifted on the return stroke and not drawn backward on the sand, particularly, if the sand is moist. When the bed is to be forked and raked this is not essential. When the bed is new the only effect of a shower of rain, during cleaning, is to delay the work while the shower lasts, but if the bed has become clogged to any extent, even if it has not been necessary to loosen with forks, a heavy shower will so compact the surface as to necessitate recleaning the portion that has been cleaned or loosening it with rakes. If heavy rain falls upon a por-

tion that has been forked and raked it will be necessary to repeat both the forking and raking before the delivery will be satisfactory. The effect of a fall of snow, during cleaning, is to increase the labor and expense and, if the snow is moist or melting, and the sand at all clogged, will require the removal of a greater thickness of sand.

In 1886 two bridges were constructed, one spanning each section of the bed. These bridges were movable, laterally, lengthwise of the bed, upon rails laid upon the coping. From the bridges platforms were suspended a little above the surface of the sand. In cleaning the men stood upon the platforms, scraped the surface of the sand and deposited the scrapings upon the platforms.

When about one-third of the bed had been cleaned the bridge, with its load, was moved to one end of the bed and the load thrown upon the bank. By this method there was no wheeling or tramping, whatever, upon the sand. One man, by this process, would clean 240 square feet of surface per hour, under normal conditions. For two or more years all the cleaning was done by two men. One section of the bed being used while the other was being cleaned.

The two men would clean one section in three days. This method was abandoned chiefly because it was impracticable to so regulate the draft upon the section in use as to avoid overworking it and hastening its clogging. There was a material saving in cost of cleaning by the use of these bridges, but in the construction of the new bed, in 1896, owing to the increased cost of construction necessary for their use, this feature was omitted. In 1897, the timber work of the bridges having decayed to such an extent as to require renewal, their use was discontinued for the sake of uniformity of operation and a better appearance of the plant.

We have now returned to the original method of cleaning.

Several methods have been used for washing sand. The one in use when I assumed charge was to cause the sand to pass over two inclined troughs, each about 12 feet long.

Near the upper end of the first trough the sand was met by small streams of water issuing from a perforated pipe under a pressure of about 100 pounds per square inch. The inclination of the troughs was such that the water carried the sand down and the force of the small jets, with the attrition of the particles during the flow, separated the silt from the sand. The water and sand were discharged into a box or tank, the sand settling to the bottom and the water

flowing off at the top carrying the silt with it. Between the lower end of the upper trough and the upper end of the lower one, was a screen through which all the sand passed on its way down. Four men were employed who washed less than 3 cubic yards per day at an average cost of about $2.38 per cubic yard. The washing was very efficient. This system was changed by increasing the number of troughs and dispensing with the services of two men thereby reducing the cost to about $1.47 per cubic yard. The work was carried on from April to December. In 1886 a trough 240 feet long was constructed and an additional supply of water taken from the settling basin. Five or six men were employed and about 2,000 cubic yards washed from March to September, at a cost of about 61 cents per cubic yard.

This method was continued, with a less number of men, depending upon the quantity to be washed, for several years. The work done by this arrangement was not altogether satisfactory, and, in 1892, a machine was put in operation consisting of a circular tank in which was a vertical, hollow shaft with perforated arms projecting horizontally from the bottom. This shaft was made to revolve slowly by means of a water motor, the water from which passed down through the hollow shaft and out through the perforated arms. The sand was placed in the tank and agitated by the revolving arms while the water flowed up through the sand and off at the top of the tank carrying away the sand and silt. The sand, when sufficiently washed, was discharged through a valve at the bottom of the tank. The work done by this machine was very satisfactory except that it was difficult to separate the leaves and algæ, particularly the latter. The cost, by this method, was about 64 cents per cubic yard. In 1895 and 1896 a single jet washer was used. By this plan the cost was reduced to about 54 cents per cubic yard. For several years the work has been done mainly by two regular employees, together with other work, and the quantity washed in a given time, with a given quantity of water, would depend upon the diligence of the men. The figures given are for ordinary work. In November, 1897, in washing and replacing the sand removed from the new bed, since it was put in operation in December, 1896, a double jet of much greater capacity was used. The sand and water from the first jet was discharged into a tank from which the water and silt flowed off at the top while the sand passed through a valve in the bottom into the second jet. From this jet the water and sand were transported

about 130 feet to a tank over one corner of the bed. The water and remaining silt flowed off from the top of this tank and the sand discharged through a valve in the bottom on the bed.

A little over five cubic yards of sand were washed and delivered on the bed, per hour, by this means. The total cost of labor at eighteen cents per hour, for washing and delivering on the bed, was 24 cents per cubic yard. Cost of water three cents per cubic yard. Total 27 cents per cubic yard. The quantity of water used was eighteen times the quantity of sand. The work was well done.

The water used was filtered water taken from the force main.

The total quantity of sand washed was 325 cubic yards. The number of hours worked was sixty.

No examinations, chemical or otherwise, for the determination of the efficiency of the bed, were made for several years after its construction. In November, 1877, an analysis was made by the late Prof. W. R. Nichols of the Massachusetts Institute of Technology. Twelve years later, in November, 1889, an analysis was made by Dr. T. M. Drown, then of the above mentioned institute; also one in 1891. The results of these three analyses, in parts per 100,000 of albuminoid ammonia, before and after filtration, also the percentage of reduction of albuminoid ammonia, of free ammonia and total solids, are as follows:

	Albuminoid Ammonia. Parts in 100,000.		Percentage of Reduction.		
Date.	Unfiltered Water.	Filtered Water.	Alb. Am.	Free Am.	Tot. Sol.
November, 1877	.0197	.0139	29	30	24
November, 1889	.0198	.0130	34	68	22
November, 1891	.0153	.0100	35	100	28

During the fourteen years from November, 1877, to November, 1891, the materials composing the bed had not been disturbed except by washing and replacing the sand. No new sand had been added. These analyses show no deterioration in efficiency, but rather, a material increase, during that period.

The results of a series of six analyses, made by Dr. Drown in June, 1893, showed a percentage of reduction by filtration, as follows:

Albuminoid ammonia	38.2	per cent.
Free ammonia	97.	"
Nitrogen, as nitrites	96.	"
Oxygen consumed	29.	"
Nitrogen, as nitrates (increased)	40.	"

Ordinarily, little or no effect is produced upon the color of the river water by passing through this filter, though one analysis by Dr. Drown, showed a reduction of discoloration as great as 60 per cent as the result of filtration.

Bacteriological examinations, three in number, made by Dr. Drown in November and December, 1891, showed percentages of removal, highest 97.7 per cent, lowest 92.4 per cent, average 94.9 per cent. An examination by Dr. Drown in January, 1892, showed percentage of removal 82.1 per cent; and in December, 1892, 91.8 per cent.

In 1895 eight bacteriological examinations were made by D. B. Ward, M. D., of Poughkeepsie, from April to December, showing an average removal of 93.8 per cent, with maximum of 98.6 per cent in June and minimum of 85.9 per cent in October. On February 14, 1896, an examination by Dr. Ward showed only 31 per cent removed; and in February 24th, but 37 per cent removed.

The death rate from typhoid fever has varied materially during the past 18 years, as will appear from the following table showing the population, in each year, from 1880 to 1897, both inclusive, as estimated from the ratio of increase in the census returns of 1890 over those of 1880, together with the number of deaths, from that cause in each year, and the number per 10,000:

Year.	Estimated Population.	No. of Deaths from Typhoid Fever.	No. of Deaths per 10,000.
1880	20,200	12	5.9
1881	20,400	10	4.9
1882	20,600	22	10.6
1883	20,800	9	4.3
1884	21,000	11	5.2
1885	21,200	11	5.1
1886	21,400	4	1.8
1887	21,600	5	2.3
1888	21,800	5	2.2
1889	22,000	6	2.7
1890	22,200	6	2.7
1891	22,400	9	4.
1892	22,600	13	5.7
1893	22,800	22	9.6
1894	23,000	15	6.5
1895	23,200	10	4.8
1896	23,400	5	2.1
1897	23,600	11	4.6
			Average 4.72

There appears to be no definite relation between the condition of the filter bed and the death rate from typhoid fever, except that the greatest number of deaths, from this cause, occur from January to April, when the efficiency of the bed is the lowest. In 1886 the condition of the bed was, certainly, the worst of any year of the eighteen under consideration, yet, the rate, 1.8 per 10,000, was the lowest of any year in that period. It is probable that the bed was not in as good order in February, 1893, when the rate was 9.6 per 10,000, as in 1892 or 1894, when the rate was much lower; it was certainly, however, in no better condition in 1886 than in 1892 and 1894. Of course the want of frequent bacteriological examinations deprives us of accurate knowledge, but these are the facts so far as they can be known without them. During the last six or eight years a higher rate of filtration has prevailed owing to increased leakage in the filter basin and the introduction of a pumping engine of greater capacity.

In 1896 an additional filter bed was constructed having an area equal to the old bed, thus doubling the filtering area. This bed consists of a single basin having a length, inside of walls, of 260 feet and width of 114 feet. Total area 29,640 square feet. The clear depth of the basin from the top of the coping to the surface of the concrete bottom, is 10.3 feet. This bed adjoins the old bed on the east and the side walls consist of rubble masonry laid in Rosendale cement mortar, faced with a brick wall laid in Portland cement mortar. The inner faces of the walls are vertical. The bottom is of concrete.

A main drain, of brick masonry, sunken below the surface of the concrete, extends longitudinally through the center of the basin. Lateral drains of 6-inch tile pipes are laid on the concrete bottom at right angles to the main drain, and 10 feet and 3 inches apart between centers. These lateral drains are covered with 2-inch broken stone. The spaces between the laterals are filled, to a depth of 10 inches, with 2-inch broken stone and 1-inch gravel. Above this is a layer of one-half inch gravel 8 inches thick, and above this, a layer of one-quarter inch gravel 6 inches thick; the total thickness of the gravel layers being 24 inches. Above the gravel is the filtering sand 31 inches in thickness. The water for this bed is taken from the settling basin of the old bed. The main drain discharges into a delivery well, 6 feet by 8 feet, on the out-

side of the north wall of the basin. In this well is a weir of cast iron, sliding in vertical grooves, by means of which the working head may be regulated. From this well the filtered water is conducted to the filtered water basin of the old bed.

The supply and delivery are controlled by gates so that the bed may be cut off at will. The sand and gravel, for this bed, were obtained from a bank at Hempstead Harbor, on Long Island.

They were screened and washed at the bank and delivered along side our dock on scows from which they were delivered to the bed by carts. Water was let on this bed on December 17th, 1896. From the beginning of 1897, nearly all the work devolved upon this bed owing to the clogging of the old one.

About the first of June, 1897, the old bed was shut off and the work of repair commenced. The sand remaining thereon was entirely removed and wasted. The gravel and broken stones, forming the lower portion of the bed, originally 4 feet in depth, was excavated around the outer wall, to the bottom, of sufficient width to permit working. The joints of the rubble masonry composing the side walls were cut out and filled with mortar composed of Trinidad asphalt and sand, applied hot and driven in with hammers. A trench about 3 inches wide and 4 inches deep was cut in the concrete bottom, next the wall, which was filled with the same mortar rammed solid. The surface of this trench, and the bottom for about 2 feet from the side walls, also the side walls, were covered with a thin coat of melted asphalt.

Rainy weather in July and August greatly hindered the work, not only by loss of time during the storms but by the time required, after the storms, to render the joints sufficiently dry to receive the asphalt mortar. This was, in large measure, overcome by the use of pulverized quick lime, which absorbed the moisture and imparted sufficient warmth to the joint to enable the mortar to adhere. After the side walls were completed the broken stones and gravel were replaced. New sand was then placed on the entire bed to the depth of 2½ feet. It was found that the stones and gravel had settled about 6 inches.

The different grades of gravel had become mixed to a considerable extent. Sand was found among the broken stones at the bottom.

Whether this intermingling was due to carelessness in the or-

iginal placing of the materials or to the operation of the bed is not known.

The sand placed on the new bed, before described, although screened and washed at the bank, still contained a sufficient quantity of loam to impart turbidity to the filtered water, in greater or less degree, for nearly six months after it was put in service. The new sand placed on the old bed came from the same bank and was screened and washed in the same manner. In order to avoid the difficulty experienced with the new bed the sand was transported from the scow to the bed by means of a hydraulic jet. An ejector was so placed at the dock as to reach the center of the scows and to raise and lower with the tide.

The ejector was supplied with water from the force main at the engine house. A line of 4-inch cast iron pipe extended from the ejector to the top of a tank on the division wall at the center of the old bed. The sand was shoveled into a hopper attached to the ejector on the scow and the water and sand delivered into the tank on the wall. The water, carrying with it the loam and silt, flowed off from the top of the tank and the sand was discharged, through a valve in the bottom, on the bed, perfectly clean, having been thoroughly rinsed in the transfer. The length of the 4-inch pipe, from the ejector to the tank, was 630 feet. Total lift, from scow to top of tank, 30 feet. Diameter of jet 1 inch. Diameter of nozzle $1\frac{1}{2}$ inches. Water pressure at jet about 110 pounds per square inch. Quantity of sand discharged 8 cubic yards per hour. This bed was put in service about the first of October, 1897, and its operation has been most satisfactory from the first.

The sand used in the original construction of the old bed was in two grades, the coarser having been obtained on the bank of the Hudson river at Roa Hook, about 30 miles south of Poughkeepsie. The finer was obtained in New Jersey. In the years of use these two grades have become intermingled somewhat with each other, and with additional sand purchased.

The following table shows approximately the mean diameters of the grains of sand comprising:

First, the lower portion of the old bed, which was removed in 1897.

Second, the upper portion of the old bed, which had been previously removed.

Third, the new sand placed on the old bed in 1897.

Fourth, the sand used in constructing the new bed in 1896.

	1 m. m. and above. Per cent.	.5 m. m. to 1 m. m. Per cent.	.25 m. m. to .5 m. m. Per cent.	.05 m. m. to .25 m. m. Per cent.
Old sand removed from old bed in 1897	37	19	41	3
Sand from upper portion of old bed	12	13	53	22
Sand placed on old bed in 1897	25	19	50	6
Sand used in new bed in 1896	24	18	44	14

The old sand removed in 1897 was considerably worn, the grains apparently rounded by the sharp corners having been broken off.

The difference in size between the sand placed on the old bed in 1897 and that used in the new bed in 1896, is due to the washing of the former which removed a considerable portion of the finer sand. The coarser grade of the old sand was very irregular in size; some grains being 6 m. m. or 8 m. m. in diameter, showing that gravel had become mixed with it. The coarser grade of the other sands was quite uniform.

Since December, 1897, both beds have been in operation. Six bacteriological examinations have been made by Dr. Ward of Poughkeepsie showing the following results :

Date.	Source of Water.	Colonies per cubic c. m.	Per cent. removed.
Dec. 23, 1897	Settling basin,	14,160	
"	Effluent, old bed,	166	98.8
"	" new bed,	872	93.
Jan. 6, 1898	Settling basin,	17,850	
"	Effluent, old bed,	132	99.26
"	" new bed,	348	98.02
Jan. 19, 1898	Settling basin,	27,000	
"	Effluent, old bed,	480	98.2
"	" new bed,	900	96.6
Jan. 27, 1898.	Settling basin,	17,850	
"	Effluent, old bed,	52	99.70
"	" new bed,	60	99.66
Feb. 4, 1898	Settling basin,	13,950	
"	Effluent, old bed,	144	98.96
"	" new bed,	88	99.36
Feb. 24, 1898	Settling basin,	19,600	
"	Effluent, old basin,	690	96.47
"	" new basin,	298	98.47

Average old, 98.56 per cent ; average new, 97.52 per cent ; average all, 98.04 per cent.

The old bed was cleaned on November 13th, and from that date until December 1st, all the water was filtered through it, the river water, meanwhile, being very roily. Since December 1st more water has been drawn from the new bed than from the old. The next cleaning of the old bed was on March 1st, 1898. The new bed has not been cleaned since December 1st, 1897.

The total cost of the original plant, as given in the reports of the department, including land, pumping plant, wells, etc., was $75,-694.82. Deducting the cost of land, pumping engine, pumping well and supply and delivery pipes leaves the cost of the bed proper with settling and clear water basins, about $62,000.00.

The cost of the new bed, exclusive of land, was $28,898.70.

For 20 years, from 1877 to 1896 both inclusive, the total volume filtered, exclusive of leakage, was 11,848,600,000 gallons. The total expenditures, in connection with the bed, during that period, was $35,468.37, which gives for the average cost of maintenance and operation, for a period of 20 years, $2.99 per million gallons.

DISCUSSION.

Mr. Hazen. I think that we are all greatly indebted to Mr. Fowler for his paper and the information which it contains. I was fortunate enough to find out several years ago that Mr. Fowler had a remarkable fund of experience and observation upon the subject which he has treated in his paper, and that he was disposed to give others the benefit of his experience. I am particularly glad that he has been able to present some of this material to the Association, and to put on record facts in regard to the first sand filter plant in America, which will be of the greatest value to all interested in the purification of public water supplies.

Mr. Fowler has been operating sand filters for a much longer period than anyone else in America. He has filtered, I think. a larger amount of water than anyone else in America, and the results that he has gotten are certainly very valuable and instructive to us, and the work of the plant as a whole is very suggestive. Mr. Fowler has labored under numerous difficulties. His filtering area has been at times inadequate; the filters were constructed a long time ago, on filled ground, and unequal settlement has resulted in cracks and in a loss of water and also in the flow of the water from one side to the other, which has seriously interfered with the operation of the plant; but in spite of all these difficulties, he has been supplying filtered water for all these years and with admirable results.

He has given you some statistics as to typhoid fever in Poughkeepsie, but to fully appreciate the significance of those statistics one needs to compare them with the corresponding statistics for other cities up and down the river, which have been using the water without filtration, and these other cities have had rates right along several times as high as Poughkeepsie has had, and when there have been epidemics in these other cities Poughkeepsie has remained pretty nearly free from typhoid fever.

I have a tabular statement of the operation of some sand filter plants giving the amount of water filtered for a year, the areas of the filters, the average rates, the area of filter surface cleaned, and the water filtered per acre between scrapings. It is the data one likes to have when one is figuring on the area of filters to be provided, and the cost of operation.

Recent Filter Statistcs.

Place.	Year ending in	Quantity filtered Million gallons.		Area of filters. Acres.	Av'r'ge daily yield. Million gals. per acre.	Filter area cleaned acres. One year.	Million gallons per acre filtered between scrapings.
		For year	Daily Average				
Altona	Mar. 1896	1,730	4.75	3.08	1.55	48.5	36
Amsterdam	Dec. 1894	3,720	10.20	10.37	0.98	139.0	27
Ashland	Feb. 1897	398	1.09	0.50	2.18	4.83	83
Berlin	Mar. 1896	13,000	35.60	25.10	1.42		
Bremen	Mar. 1896	1,220	3.34	3.21	1.04	32.5	38
Breslau	Mar. 1896	2,960	8.10	5.12	1.58	40.0	74
Brunswick	Mar. 1896	840	2.30	1.48	1.56	13.3	63
Copenhagen	Dec. 1895	2,330	6.40	2.88	2.22	44.7	52
Dordrech	Dec. 1894	365	1.00	0.56	1.79		
Frankfort on Oder	Dec. 1895	310	0.85	0.37	2.38	2.9	107
Hamburg	Dec. 1895	11,700	32.10	34.00	0.94	275.0	43
Hudson	Dec. 1895	535	1.46	0.74	1.98		
Konigsburg	Mar. 1896	1,085	2.97	2.70	1.10	35.0	31
Lawrence	Dec. 1896	1,101	3.02	2.50	1.20	30.0	37
Liverpool—							
Oswestry	Dec. 1896	4,460	12.30	4.90	2.52	100.0	45
Rivington	Dec. 1896	4,060	11.10	6.02	1.84	58.0	70
Total	Dec. 1896	8,520	23.40	10.92	2.14	158.0	54
London (rivers only)	Dec. 1896	72,482	198.00	123.75	1.60		
Lubeck	Mar. 1896	1,600	4.38	1.40	3.13	24.4	66
Magdeburg	Mar. 1896	1,950	5.35	3.76	1.42	65.0	30
Mt. Vernon	Dec. 1896	608	1.66	1.10	1.51	9.2	66
Posen	Mar. 1896	346	0.94	0.70	1.35	10.4	33
Poughkeepsie	Dec. 1896	664	1.82	0.68	2.68	9.0	73
Stettin	Mar. 1896	1.030	2.83	2.26	1.25	15.5	66
Stockholm	Dec. 1895	2,375	6.50	2.78	2.33	70.0	34
Stuttgart	Mar. 1896	1,220	3.34	1.66	2.04	17.7	69
Zurich	Dec. 1896	2,360	6.45	1.66	3.88	30.0	79

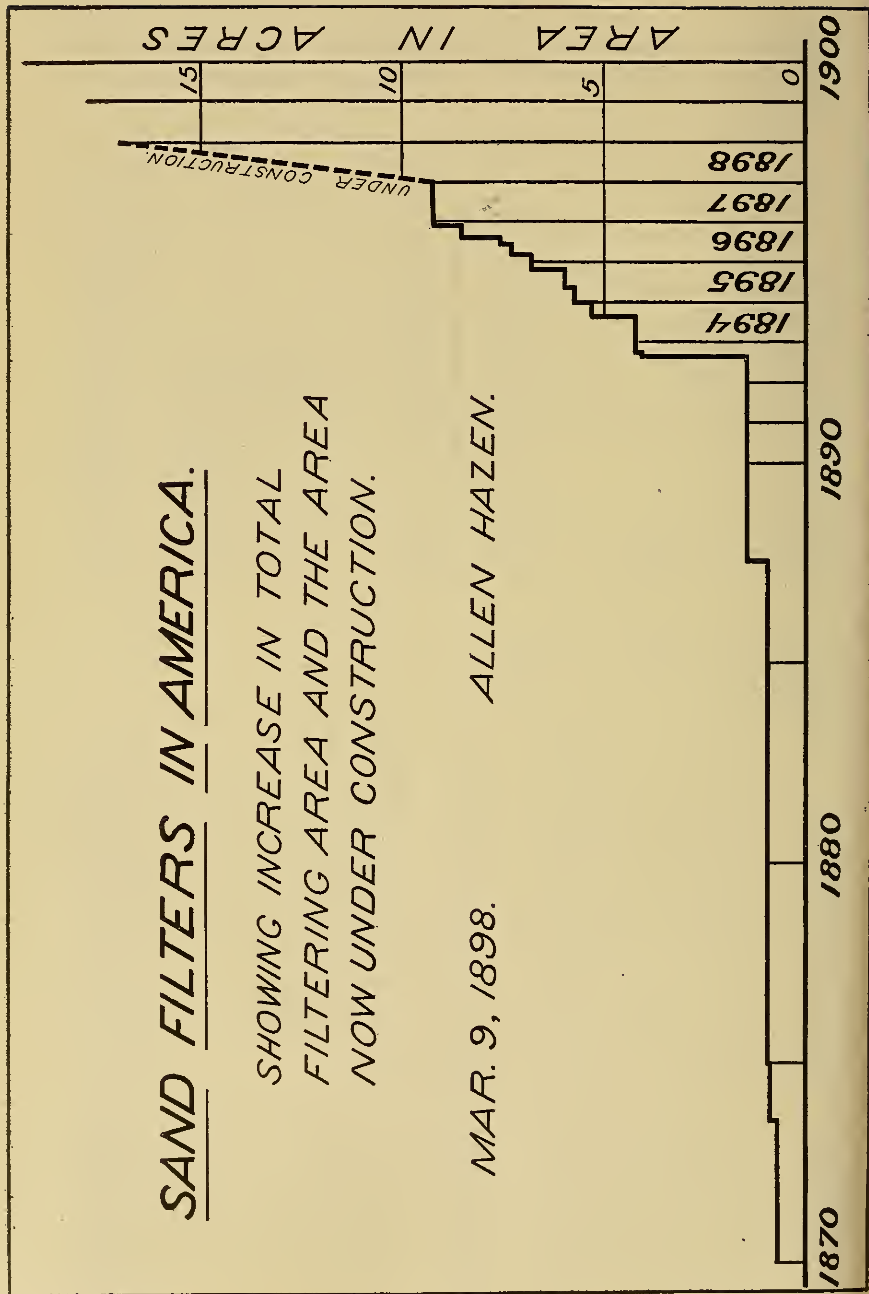
I have also a table of sand filters now in use in the United States and Canada, with their approximate areas, and the dates when they were built, and a list of filters under construction.

SAND FILTERS IN AMERICA.

Place.	Area, Acres.	Built.	In Operation.	Total Area to Date.
Poughkeepsie N.Y., (original)	0.68	1872		0.68
Hudson, N, Y., (original)....	0.21	1874		0.89
St. Johnsbury, Vt...........	0.05	1875(?)		0.94
Hudson, addition...........	0.53	1888		1.47
Nantucket, Mass............	0.11	1892	Aug. 8, 1893	1.58
Lawrence, Mass.............	2.50	1892-3	Sept. 20, 1893	4.08
Ilion, N. Y	0.14	1893	Sept. 30, 1893	4.22
Mt. Vernon, N. Y............	1.10	1894	Aug. 1, 1894	5.32
Grand Forks, N. D	0.42	1894	Jan. 4, 1895	5.74
Milford, Mass...............	0.25		1895	5.99
Victoria, B. C...	0.83		1895	6.82
Ashland, Wis................	0.50	1895	Feb. 5, 1896	7.32
Lambertsville, N. J	0.28		May 4, 1896	7.60
Far Rockaway, N. Y....	0.92	1896	July 1, 1896	8.52
Poughkeepsie, addition.....	0.68	1896	Dec. 17, 1896	9.20
Red Bank, N. J........... .	0.03	1897	June 5, 1897	9.23
Under Construction.				
Somersworth, N. H....	0.50			
Nyack, N. Y............ ...	0.39			
Albany, N. Y..	5.70			
Rock Island, Ill.............	1.20			

A diagram herewith presented shows the aggregate filter area up to the various dates mentioned, starting with the Poughkeepsie plant back in 1872, followed by the original plant at Hudson, built in 1874, and the little plant at St. Johnsbury, and by the others. The first great increase came with the Lawrence filter and since that time the increase has been rapid. There are something over nine acres of sand filters in use in North America at the present time, and enough more filters are under construction to bring the total area up to something over seventeen acres. The increase has practically all been in the last five years.

I want to ask Mr. Fowler, as to the behavior of the filtered water in his open distributing reservoir. With surface waters open distributing reservoirs are generally considered as good or better than covered reservoirs. With ground water supplies it is considered necessary to exclude the light, to prevent objectionable vegetable


SAND FILTERS IN AMERICA.
SHOWING INCREASE IN TOTAL
FILTERING AREA AND THE AREA
NOW UNDER CONSTRUCTION.
MAR. 9, 1898.
ALLEN HAZEN.
AREA IN ACRES
0
5
10
15
UNDER CONSTRUCTION.
1870
1880
1890
1894
1895
1896
1897
1898
1900

growths. Now filtered river water in its characteristics comes between ground water and surface water, and it has been pretty commonly thought in some places that it was necessary to store filtered water in covered reservoirs. I would like to have Mr. Fowler state, if he will, whether he has observed any objectionable tastes or odors from the growth of organisms in his distributing reservoirs; and, if there is anyone here from Lawrence, who knows about the Lawrence conditions I wish we could have some information in regard to Lawrence in that connection, and, also, as to whether there is any difference between the new high service reservoir at Lawrence, which is covered, and the old reservoir, which is open?

Mr. Clark. In regard to that matter I will say that at Lawrence they have had in the open reservoir a growth, one or two summers since the filter was put in, of fresh water sponge, which has caused a slight taste and odor in the water, but the sponge grew there before the water was filtered. That is the only thing we have noticed at all. In the stand-pipe the past year there has, of course, been no growth, so far as we could observe, and there was only a very slight growth in the reservoir last summer, nothing that anybody noticed except in a few houses.

There is one thing Mr. Fowler spoke of I should like to mention, and that is the growth of this algæ on the surface of the filter. His filter, I understand, is a continuous filter, and is covered with water except at times of scraping. At the experiment station we have had in operation for some years both continuous and intermittent filters. They were both uncovered until the fall of 1895. During the summer of each year that we operated these filters before covering, there was a growth, generally in September, I think, of this spirogyra, on the surface of the uncovered continuous filter, but it did not grow on the surface of the intermittent filter; neither has it occurred to any extent at the Lawrence city filter. There has been a slight growth in patches here and there from time to time, but nothing that has caused any trouble. Since the fall of 1895 the experimental filters at the station have been covered, that is, we have a board covering over them about three feet above their surface, and there has been no growth of this spirogyra on the filters since that time.

Mr. Fowler also says that the filtration of the river water at Poughkeepsie has not affected the color to any extent. With our

filters at Lawrence we remove about from 30 to 50 per cent of the color at different seasons of the year. In the fall sometimes, when the river water is high and very highly colored with the washings from swamps or woodlands up the river, we do not remove more than 25 to 30 per cent; in other portions of the year we remove 50 per cent. It is different with the Lawrence city filter, of course. As you know, that is built upon a mud bottom, and we have coming into it ground water containing considerable iron, which colors the entire water from the filter to a certain extent. That is to say, the ground water with the iron gets in with the filtered water, and causes an increase of color over what the real filtered water has, but as a general thing, as an average for the year, we have removed 30 per cent of the color from the river water, even after the addition of this iron water.

Now, in regard to the death rate at Lawrence before and since filtration, I presume it is pretty familiar to most of you that for a number of years before we had the filter, typhoid fever was epidemic in Lawrence each year, and we had death rates ranging from 10 to 12 or 13, I believe, per 10,000 inhabitants. The year the filter was built, 1893—it was put in operation the 20th of September—the death rate was a little over 8 per 10,000; in 1894 it was 5 per 10,000; in 1895 it was 3.07 per 10,000; in 1896 1.86 per 10,000; and in 1897 1.62 per 10,000. The death rate from typhoid has certainly gone down. I may say that a little while ago I heard two doctors and one of the undertakers in the city complaining bitterly of dull times in Lawrence. They stated that their occupation was practically gone in the months of the year when they were formerly very busy. [Laughter.] I was talking with a stablekeeper the other day also who has in his stable the wagons and horses of two undertakers, and he said that they had been in about every day for the past two weeks, saying that nobody was dying, and they didn't know whether they should be able to pay their bills; in fact, I think he said they hadn't paid their bills. [Laughter.]

I don't think I have anything further to say in regard to filtered water, except that the death rate and the disease records of the city show that apparently other diseases beside typhoid fever have been lessened. We sometimes have complaints of the appearance of the water and the taste of the water as it is delivered to the consumer. Generally those complaints are from people who live

near the ends of pipes, dead ends, so-called; and there is an accumulation of iron there and stagnant water. But the people who complain the most bitterly, and whose cases we look up by going to their houses to take samples, always say when we get there that the water has no odor that day. [Applause.]

Mr. Fowler. Mr. President, just briefly to answer the questions asked, I will say, first, with reference to odor in our reservoir water, that since I have been in charge there has been no difficulty experienced whatever. I am told that previous to that time there was an occasional odor, that is, this fishy odor which is very common, and it has occurred once or twice since in the dead ends, as was referred to by Mr. Clark; but during my administration no trouble has occurred in the reservoir.

With reference to our filter being continuous, it is continuous in that most of the time the basin is covered, particularly in the winter; but our pumping is not continuous. We pump generally 3½ to 4 days in the week, and the filter works during that time, though we aim to keep the water on the filter. But in the summer time we have sometimes allowed the water to go off the filter and drain dry, hoping that the rays of the sun would kill the alga growth, but it does not do so with us. As soon as we turn the water on it begins to develop again.

With reference to typhoid fever, you notice two instances in my table of very high rates. Now, it is a fact that a number of the cases of typhoid fever in our city originate outside, because we have quite a large number of transient students in our college, and typhoid fever occurs frequently among those, and perhaps the variation in the rate may be due to some such fact as that.

Mr. Clark. There is one thing I should like to add to what I said before, and that is that we still have canal water piped into some of the mills, and a number of the deaths that go to make this record of typhoid fever are of people who have acknowledged drinking the canal water. We have had two deaths from typhoid fever thus far this year, one in January and one in February, and in one case the man acknowledged that he had been in the habit of drinking canal water at the mill.

Mr. Haskell. I would like to ask Mr. Clark if it is not probable that there is less danger from typhoid fever from the use of the filtered water in Lawrence, water taken from the Merrimac and

filtered in their filters, than there would be from an ordinary surface water supply unfiltered?

Mr. Clark. I don't know just what an ordinary surface water supply is. You can have a surface water supply that is perfectly pure, I suppose, from a pond that is not contaminated at all. There are a number of surface supplies in Massachusetts that are contaminated to a certain extent and used without filtration, that is, they are liable to contamination, and I think by using such a water there is more liability of typhoid fever occurring, certainly, than with a filtered water.

Mr. Fowler made some statements in regard to the bacteriological efficiency of the filter. Our filter at Lawrence does better work than his, better bacteriological work. We make analyses of its effluent every day for the largest portion of the year, and I can say that for the past three months, while the average number of bacteria in the river water has been towards 6,000 or 7,000 bacteria per centimetre, I don't think there has been but one or two days when the numbers in the filtered water have averaged over 50, generally down to 25 or 30. We are making a good many additional tests this year. We test the filtered water every day for the presence of coli, the characteristic sewage bacteria; and, while I am not ready to make any statements in regard to those results, I will say that they certainly show an efficiency in that respect that can hardly be shown by percentages. There is a practical elimination of sewage bacteria. And if we do find any, we have generally found a cause for it. There has been something going on in the pumping station, the testing of the pump, and the water allowed to flow back over the floor of the station into the pump well, or something of that sort.

Mr. Haskell. Will Mr. Fowler explain the algæ growth on the bed of this filter?

Mr. Fowler. The algæ growth to which I referred is simply the growth of the plant. It does not affect the water in any way I am aware of, either by odor or taste. It simply grows on the top of the sand and stops filtration, that is the only way it affects us; and the only way we can get rid of it is to stop filtering, drain the bed, and take it off with shovels. It develops on the bed, it is not in the water and taken out on the bed, but it grows on the sand. Perhaps the germs may be in the water, but the algæ, the plant itself, grows on the sand. It will start in a little bit of a speck and grow in a

circle like a dollar until the whole bed is covered as with a blanket.

MR. THOMAS. I would like to inquire of Mr. Fowler if the filtration of the water has increased the hardness to any appreciable extent?

MR. FOWLER. So far as chemical examinations have been made there is no difference, I believe, between the hardness of the unfiltered and the hardness of the filtered water. The total solids are reduced, of course, but I think there is little if any difference in the hardness.

THE PRESIDENT. Professor Sedgwick, will you say something on this subject?

PROF. SEDGWICK. Mr. President, and gentlemen of the Association, I have suggested to your secretary that this paper is so valuable and so full of material that it ought to be thoroughly discussed by all the members present, who ought to embrace this as a rare opportunity; and that to that end I should be very glad to defer what remarks I was going to make in the form of an informal talk to another occasion. And with that in view, I should like to say one or two things about Mr. Fowler's paper.

This is really a rare occasion. Here is the one man in the United States who has had a long experience with sand filtration of a highly polluted water, in a northern winter, with the ordinary American community to deal with and get his money from—a longer experience, as Mr. Hazen very truly says, than any other man in the United States. He has used a filter built by the eminent Mr. Kirkwood, and one which, so far as I can judge, has on the whole efficiently protected the citizens of Poughkeepsie from typhoid fever.

One or two questions which have been asked suggest the idea that should always be kept in mind, viz:—that typhoid fever does not come entirely from water, so that when the typhoid rate is reduced to a low point, as it has been in Poughkeepsie, and as it has been in Lawrence, we may say that there is no more typhoid fever in a city of that kind with these low figures than there is in many cities having absolutely unobjectionable water supplies, derived from very pure sources. It is necessary to make this statment very squarely and flat-footedly, because one or two engineers in particular have from time to time insisted that as long as there was any typhoid fever in a city, the filter, or water supply, whatever it might be, must be at fault, and that the only remedy is to use distilled water.

Well, that is absolutely false. The right test in these cases is to see whether the amount of typhoid fever remaining after the introduction of the new system, whatever it may be, is any greater than would be found in a similar city supplied with water drawn from perfectly unobjectionable sources.

Now, in the case of the Merrimac river water it is easy to get at that, because there are cities above and below Lawrence that have remarkably good water supplies. They are of the same climatic situation, they have the same late winters and early falls; and they are under the same Divine Providence, which some people still think is responsible for typhoid fever; they are occupied in the same or similar industries, they have just about the same surroundings, the people in the different cities are of similar classes; and with the rate in such cities the rate, for instance in Lawrence, should be compared, and not with the figure zero. There is not a city in the country that hasn't some typhoid fever, and there are many cities in the country that have water supplies which cannot be conceived of as polluted.

It seems to me that the results given here, especially these results in more recent years, when Mr. Fowler has had the advantage of modern sanitary science, are figures which are highly noteworthy; and even the earlier figures, when the filter was run without the modern knowledge of filtration, are also very helpful. The paper is not only full of practical value, but as I look at it has an historic importance; and I for one, sir, am very glad you have consented to read it before this Association, in order that it may go into our JOURNAL and be accessible to all the members of the New England Water Works Association; because we, who are members, believe that this Association does not yield the first place to any such association in the world. We are glad to get papers of this kind, and we appreciate them when we do get them. They are genuine contributions to sanitary science, as well as to the science of water works engineering and management.

I should say that the city of Poughkeepsie had been fortunate in its superintendent. And, while that may seem an empty compliment, let me assure you that it is not so, for there is in all these water supplies the human element. Mr. Fowler discovered it when he found his engineers letting the water run over into the waste-pipe to avoid cleaning the filters. There will always be a human element

in the management of everything. Locomotive engineers will once in a while disregard signals and have collisions, rear-end collisions and the like. Admirals, like the English Admiral on the warship Victoria, will once in a while give directions to turn when there is not room to turn, with the result that they and their ships go to the bottom. There is a human element in all these things, and that water supply is to be esteemed fortunate which has for its administrative officer a man who is persevering, watchful, intelligent and faithful; and such, I believe, most of the water works in New England do have, and all over the country, for that matter. They have to have them, or the people will come to grief.

With regard to the question raised by Mr. Haskell, I had come with considerable talk bottled up on that subject. I am proud that more than a year ago I was able to read a paper before this Association, and that it is printed in our reports, on the Protection of Surface Waters from Pollution. It was the first thing of the kind, so far as I know, that has gone into print, but it is not going to be the last. There have been very serious epidemics in England, particularly within the last six or eight months, three above all others—Maidstone, Lynn, King's Lynn, I believe the full name of it is, and Horsley; where in at least two, and perhaps in all of the cases, a surface water, which had previously been supposed to be pretty pure, that is it was by some, although it had been condemned by others has been the source of very serious damage indeed, and I had come prepared to speak on that subject. But I came with this distinct understanding—it was possible Mr. Fowler might not turn up, and I offered to come only as a stop-gap. I do not propose, therefore, to distract attention, if I could distract it, which I very much doubt, and which I certainly do not want to do, from this very valuable paper. I think an afternoon where we have had reported an experience of seventeen years from a man like Mr. Fowler, on a subject which is certainly the coming subject of water supply all over the world, is an afternoon which has been amply filled, and I do not propose to bring in any other subject at this time.

I do wish to say, however, that Mr. Haskell's question is very well raised. There is no doubt whatever that a surface water which has some little brook sneaking into it, over which privies are hanging, and into which typhoid dejecta are dropping, is a more serious menace to the people using that water than is any

rather badly regulated filter. I would rather take my chances with sewage polluted water filtered intelligently and well, than with a surface water I knew nothing about. And if the time should come when I could give you some extended talk on that subject in amplification of my paper of a year or more ago, I should be very glad to do it, because we are learning every day how serious, as population increases, are the dangers from surface waters not properly watched. It is the watching of the watershed that is our salvation in these cases, and the cleaning of it up. These recent epidemics have set all England in an uproar. I am not exaggerating it one bit. The people are more stirred up in regard to water supply there than they have been for probably twenty-five years.

I happened to be over there this summer, but, unfortunately, the Maidstone epidemic did not occur until just after I reached home. I should have been very glad to have been there and brought you a report of what I could have found on the spot. Since then there have been that great epidemic and two more. It really seems today as though American sanitation in water works affairs was far superior to the English system and practice. The fact is England has been lying on her oars in this matter while America has been forging ahead. And it is a matter of national congratulation, I think, that our water supplies are, as I believe they really are on the whole, our surface water supplies, in better repair and in better condition today, than the average English surface water supplies, for several reasons, which I will not go into now. I wish personally to thank Mr. Fowler for the trouble and time he has taken to prepare and to put this paper on record. It is a matter of congratulation that we have his experiences, and I hope he will come often and give us further chapters from his experience.

Mr. Haskell. There is one other point I wanted to develop to a certain extent in relation to Mr. Fowler's paper, and it is something that ought to seem perfectly surprising, and that is the cost of operating a sand filter. When we think of the vast amount of money individuals are spending in trying to operate some of their filters—I know where they are changing the materials in their filters every three or four weeks, and purchasing quartz in large quantities, —here we find a man who has operated a filter for a long period of years, who has succeeded in getting 97 per cent bacterial efficiency from the use of his filter for a long period, whenever there have

been examinations made, and he has done it all at an expense of less than $3 per million gallons.

Now you all know that the bacteria are the dangerous things in the water. The disagreeable things may not be so fully eliminated, but the dangerous ones have been eliminated by Mr. Fowler to the extent of 97 per cent. And there is hardly any city that could not afford to add $3 a million gallons to the cost of its water, when very likely it costs $85 or $90 a million gallons for maintenance and operation. Calling it $85, it wouldn't add but a small per cent to filter the water. And when we know how easy it is for a camp of gypsies or somebody else to catch around on the edge of a water supply, and stop there, and perhaps send typhoid fever down into the service, or for some of these Italian camps to be located around on a water supply, and that one or two cases of typhoid fever there can produce an epidemic in a city, it does seem as though the attention of everyone ought to be fully brought to the importance of these filters, and also to the cheapness with which they can be supplied and operated.

PROF. SEDGWICK. There is one point which Mr. Haskell's remarks remind me of, and which I think ought to be borne in mind when we speak of the efficiency of filtration. We speak, Mr. Fowler has spoken, and Mr. Clark has, and we all do, of the reduction of bacteria as 97, 98 or 99 per cent, and so on. Now what does that mean? It means that there are so many bacteria to a cubic centimetre in the water before filtration, and so many after filtration, and we speak of that as a reduction of so many, or so much per cent. But it ought always to be borne in mind that the real reduction of applied bacteria may be very much greater than that, and for this reason: It often happens that a natural filter is a place where bacteria, fed as they are by a constantly passing stream of water, may somewhat multiply. Those, of course, will only be the harmless water bacteria, at least that is a fair assumption. And I know it has been tried at Lawrence to find a term which should express the thing a little more exactly than to say there was a reduction of 97 or 98 per cent. It is a difficult thing to do, because if you try it, you will find that any expression which really states all the facts is rather long and cumbrous.

There are a great many house filters, for example, which actually give out more bacteria than they take in, but they are perfectly

harmless bacteria, so far as we can judge, from the fact that the people drinking the water seem to be in excellent health and to have no trouble from them at all. But if there are 1 or 2 per cent of bacteria still found in the effluent water, I do not think there is any doubt at all that a certain proportion of those have got to be charged up to the natural development of the bacteria in a filter to which food is coming all the time. It is a place where bacteria reside, and if they reside there they will multiply more or less, so that the real efficiency is higher than the apparent efficiency in all these cases.

And then you will remember that you are dealing with a germ like the typhoid germ, which is all covered over, as it were, with whiskers, it has cilia all over it, and to pass that through sand is very much like trying to pass, for example, a hair brush which has bristles not merely on one side, but all around it. That is a kind of thing that tangles up there far more than the bacteria which are not covered with these lashes, or, as I have roughly called them, whiskers, which cause entanglement. And I haven't the slightest doubt in the world that the real efficiency of these sand filters is far greater than the apparent efficiency. So when it comes up to 99 per cent., for instance, the figure very likely is 100 per cent. of the bacteria actually put on, and especially of bacteria like the typhoid germ. Unfortunately it is not easy to state that.

Everybody assumes that if we put on 100 bacteria, 99 of those bacteria stay there and one of them slips through. Well, sometimes undoubtedly they do slip through, and sometimes undoubtedly they do not slip through, but those which come out below are really those which were raised, perhaps, on the underdrain or in some such place as that. So that the real efficiency of these filters on the whole, in my judgment, is a good deal higher than the apparent efficiency, and for good reasons.

Mr. Haskell. There is one matter, which is very important, connected with the construction of these filters, about which I would like to get some information from Mr. Clark or Prof. Sedgwick. There was a time when we did not consider there could be more than 750,000 gallons of water per acre properly filtered with a good bacterial efficiency. Now, as I read the reports of the State Board of Health, I find that they are increasing in their bacterial efficiency. I really think they have got nearly to ten million gallons per acre

per 24 hours, and I think they have maintained for the year continuous work as good as 99.70 to 99.73 per cent. Now that means a good deal in the construction of a filter, and if we can get that fine work through a continuous filter, I should like to know it, and I didn't know but Mr. Clark or Prof. Sedgwick could tell us.

Mr. Clark. We have never operated any filters at so high a rate as 10,000,000 gallons except for a few weeks at a time, and then we have got apparently very good results. But, taking the filters which we have been operating for a number of years at the experiment station, the average rate of filtration has been rather less than 4,000,000, three million six or seven hundred thousand, with our largest and best sand filters. I myself believe that with careful handling of a small plant, with intelligent direction, you can perhaps filter a water, something nearly as badly polluted as the Merrimac river water, at a rate approximating 4,000,000 gallons per acre daily, but I think that a safe rate is 3,000,000 gallons, with the care which the filters on a large scale would generally receive. I, certainly, if I was building filters, or recommending filters for any municipality, should not advise that the rate be over 3,000,000 gallons per acre daily. I think that the economy in running a filter at the rate of 3,000,000 gallons is greater than at the rate of 5,000,000; that is, I think there will be more scraping, more washing of sand and changing of sand at the rate of 5,000,000 than at the rate of 3,000,000, that is, a greater cost per million gallons of water filtered. This whole question depends, however, upon the character of the water to be filtered.

Mr. Fowler. Mr. President, may I be allowed one word with reference to that point. I think that in examining the paper, which the gentlemen have been so kind as to speak so favorably of here, one thing will be prominent, and that is that a larger area is necessary in constructing filters than just the area sufficient to do good work when everything is in perfect order. Therefore, if 3,000,000 gallons, which I fully agree with Mr. Clark ought not to be exceeded, is the quantity wanted per day, we should have a certain amount in excess, in order that we may always have our area for 3,000,000 gallons per day in perfect order. I find that the great trouble with my work. I worked for 16 years with one filter

of the size I gave you, two-thirds of an acre in extent. Now we have just built a new filter equal in area to that, giving us one and one-third acres. If we were to operate an uncovered filter, I should not consider the plant perfect for use until we had one more filter of one-third of an acre in area, that is in order that it might be in perfect order at all times. Of course that is something I don't expect to get, probably, during my administration; but I shall not say that our plant is perfect for our city until we have a little more surface, so I may always have the two I now have in perfect order.

MR. HASKELL. It seems to me that perhaps Mr. Clark is a little too modest about telling us of the final results they have secured up there in Lawrence in some of their experiments. My memory is not as good as it was once, but I have read the reports each year, and if I remember correctly, filter A, I forget the number now, it may be 58, has been operated for 11 years. They operated it in different ways and they did very good work with it, and they finally thought they would construct a filter as near as they could under the conditions which would apply to an ordinary water supply, and they have operated that now, I should think, about six years. It was run at the rate of over 4,000,000 per day of 24 hours, and practically run continuously for the term of four years. And I think by the report for 1896, it appears that for the three years run at that rapid rate continuously the percentages were 99.70, 99.73 and 99.50. Now it did do nearly as good work as that, didn't it, Mr. Clark, although you wouldn't fully recommend it, and it did it under conditions copying as near as possible a practical filter!

MR. CLARK. I said, Mr. President, that I thought small filters, with careful watching hour by hour, with intelligent management, could be operated at these high rates. When I said "small filters," I meant filters such as we are running at the Lawrence experiment station. I have no doubt however that a filter with a surface area of an acre or half an acre, receiving water like the Merrimac river water, can be operated, if extreme care is given to it, at a rate approximating 4,000,000 gallons per acre daily; but I believe a safer rate is a little lower than that, and I do not think, with my

present knowledge of the subject and my present experience in operating filters, I should ever advise a rate as high as 4,000,000 gallons, with such water as the Merrimac river water. Still we have got for the past four years extremely good results with an experimental filter, 17 feet in diameter, running at a rate approximating four millions; I don't think the average has been four millions. I think it has been about 3,600,000 for the four years.

Mr. Hazen. I have come to the conclusion that different waters can be filtered at different rates, and that it is perfectly possible to filter some waters with high bacterial efficiency, at rates at least twice as high as can be successfully used with other waters. I am not going to tell you all the conditions which influence or control the possible rate of filtration, principally because I do not fully understand them myself, although we are learning something about them. In regard to the efficiency that is secured by the operation of filters, there is the efficiency which is gotten when the filter is in perfect condition, and there is the efficiency which is gotten when the filter is in a defective condition. And I think that the lower bacterial efficiencies resulting from defective conditions have been a good deal more common than has been generally supposed.

One of the commonest defects of a filter plant is for the unfiltered water in some way or other to get around the sand into the under drains. Mr. Fowler told you how it went through his ventilator pipes. Filters have been built without any ventilator pipes, and they work just as well without them, and this danger is avoided. Sometimes the sand will cake a little, and it will draw away from the wall, and the unfiltered water will run down the wall. We have corrected that by putting some little ledges or jogs in the wall, and the sand makes a better joint on a horizontal surface than on a vertical surface. That was a good idea as far as it went, but even with those jogs the masonry may sometimes crack, and the water leak into a crack above the sand line and come out of a crack below the sand line. Now we are building filters keeping the gravel back from the outside walls all the way around. It perhaps reduces the area of the filter a little theoretically, but if the water comes down the wall in some way, it has to pass along the bottom through the sand before it gets into the underdrains. We

keep finding out such things as that. Mr. Haskell asked me today if we were ready to build a perfect filter. I told him no, we didn't expect to build a perfect filter for a long time yet, but we are building as good filters as we can, and are learning more about how to do it all the time, and are building filters which will do very good work, even if they are not perfect.

LOSS OF WATER FROM PIPES.

BY F. H. CRANDALL, SUPT., BURLINGTON, VT.

[*Read February 9, 1898.*]

The determination of the loss of water from any considerable system of underground piping is at best problematical and does not admit of definite unquestionable solution, but in the case which I will endeavor to present for your consideration, some of the difficulties ordinarily encountered have been eliminated.

Systems, even of such small extent as that to which your attention is invited, on which for months at a time there is no occasion to open public fire hydrants, on which there are no large manufacturing concerns using water for fire purposes and on which all ordinary legitimate use is metered, are not numerous. On the Burlington High Service, however, it has recently come about that these conditions obtain.

By far the larger portion of the pumpage on this service is accomplished by a motor, an auxiliary steam plant being used only when for one reason or another it becomes necessary. The works were built in 1880 and 1881 and now supply the University buildings, the State Agricultural Experiment Station and farm buildings, two Roman Catholic schools, one hospital and five summer residences with innumerable fixtures, beside 45 dwellings, nearly all of which are supplied with modern conveniences in plumbing. Some of the mains were laid in rock cut and some are for the greater portion of the year, below the ground water level. No more than usual care was taken in the laying, and no more than the usual amount of trouble has been experienced from them since. The work was not contracted.

The average pressure on fixtures is about 35 pounds, and on the majority of the services (on those of all the larger consumers), a main tank with supply controlled by a ball-cock covers nearly all the fixtures.

The service comprises an iron tank of 2,260 cubic feet capacity, 9,671 feet of cast iron mains from 4 to 8 inches in diameter, and about 1,560 feet of 4-inch cement mains, with six public fire hydrants, one 4-inch and two 2-inch services supposed to be used for fire purposes only, 62 metered taps through which water is used for domestic purposes, one 3-inch metered elevator service, one 2-inch overflow, metered, and one 1¼-inch metered service used to supply power for operating valves of the motor.

The meters in use on the service are of the Crown, Nash, Empire, Bee, Lambert, Union Rotary, Union Piston, Disc and Trident make. Each of the meters used on the service at the time of setting, registered on full size ⅛-inch and 1-16-inch streams not more than two per cent fast nor more than 3 per cent slow. By sizes, the meters in use are one 3-inch, two 2-inch, two 1½-inch, seven 1-inch, seven ¾-inch, forty-one ½-inch, and five ⅝-inch.

As the discharge of the motor is conveyed to the tank by way of the distribution system, and thus far conditions have not been favorable for accurate measurement, the losses in the pump can be got at only by estimation.

The plunger in the pump end of the motor, which works against about 41 pounds static, 43 dynamic head, is 4 and 7-16-inches in diameter, and is provided with a double cup leather packing, which has frequently been found, when the plunger is not in motion, to be absolutely tight at different points of the stroke. In motion a small leakage is developed. There is also leakage of the ports, and though at different times when the motor has been opened for repairs, the high service pressure being applied on the pump side, there has been no leakage noted through the leather packed stuffing-box between pump and motor, in practice there must be some leakage at this point.

The motor and pump are set up tandem, and at the other end of the rod, to which is attached the pump plunger, another and a larger plunger in the motor barrel is attached. These plungers and their rod passing through the aforementioned stuffing-box in the head common to both motor and pump have, when at work, more or less rotative motion.

The leakage through this stuffing-box, between the pump and motor, cannot conveniently be separated from that through two 10-inch gates under the low service pressure (about five pounds). All

three together have frequently been found to amount to less than one per cent, and in the different tests made it has developed that reliable information is not to be obtained from the measurement alternately for equal intervals of the total leakage and that from the gates alone, as the leakage of the two gates alone was often in excess of that of gates and stuffing-box taken together.

The suction and discharge ports of the motor pump are each 12 in number, about three inches in diameter and capable of one-half inch lift. The motor runs at from 4 to 32 strokes per minute and will not run many minutes at the maximum speed. The average is about sixteen strokes per minute.

Beside the losses common to all pumps a further source of error in the counter measurement in this case is the shortening of the stroke on small streams such as obtains in some meters, and which in this case at times reaches three per cent of the stroke. It is not, however, expected that in practice the motor will be required to run for any considerable length of time on a very small flow.

In the endeavor to obtain some idea of the tightness of the pump plunger when in motion, motion was imparted to it when under pressure by means of a rod threaded for the full length of the stroke and operated through a threaded hole in a bar bolted across the opening made by the removal of the cylinder head.

The motor is supplied with a regular pump counter and the record of its strokes is probably as accurate as is generally obtained. The pumpage of the steam plant was, perhaps, not as accurately determined. It was taken to be the increase in depth of water in the tank during the time of its operation, which usually took place at times when there was little or no consumption.

The records for the two periods into which the total period may be divided, during one of which the steam pump was used and the average daily consumption was about 4,770 cubic feet and during the other of which the steam pump was not used and the average daily consumption was about 3,552 cubic feet, do not differ materially in the percentages not measured.

In taking statements of the meters recording the consumption, about two hours are consumed, and the counter of the motor is read during that time. For very short periods the pumpage during the time of taking statements and a slight variation of depth in the tank tending in the same direction would have a noticeable effect,

but for long periods any error which could arise from these causes is so slight as to be neglectable.

In determining the correction to be applied to the counter record for losses on the pump, taking the leakage of the ports at the mean noted during several tests, made under static pressure, that of the plunger at the mean noted while moving with considerable less than its usual velocity against the static pressure and that of the stuffing-box at an arbitrarily chosen amount equal to one-half that of the plunger, we have an aggregate loss, under the conditions noted of about one per cent, and for purposes of estimation we will assume the losses under working conditions at five per cent.

Records are at present obtainable of the pumpage and consumption on this service for a period of eleven months, during which every legitimate use of water, except such as made by the water department, was supplied through meters. During the period under consideration there was no occasion for the use of water for fire purposes on the high service.

During the first eight months for which records are kept, the steam plant was called upon but five times. The total amount of water handled was 1,144,907 cubic feet. 1,088,563 cubic feet, or about 95 per cent by the motor, (as per indicator), and 56,344 cubic feet, about 5 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

729,282	cubic feet,	about	64	per cent,	was metered to consumers.
193,285	"	"	17	"	" " " motor.
39,040	"	"	3	"	" " " overflow.
27,630	"	"	2	"	" estimated to consumers.
57,245	"	"	5	"	" the estimated loss in pump.
98,425	"	"	9	"	not accounted for.

During the last three months for which records are obtainable, the steam plant was not called upon at all. The total amount of water handled was (as per indicator) 319,734 cubic feet. Of this indicated pumpage,

230,375	cubic feet,	about	72	per cent,	was metered to consumers.
40,360	"	"	13	"	" " " motor.
1,680	"	"	5	"	" " " overflow.
2,024	"	"	5	"	" estimated to consumers.
15,986	"	"	5	"	" " loss in pump.
29,309	"	"	9	"	not accounted for.

During the entire period for which records are available, eleven months ending February 1st, 1898, the total amount of water handled was 1,464,641 cubic feet—1,408,297 cubic feet, or about 96 per cent by the motor (as per indicator) and 56,344 cubic feet, about 4 per cent by the steam plant. (Determined as before stated). Of this indicated pumpage,

959,657	cubic feet,	about	65	per cent	was metered to consumers.
233,645	"	"	16	"	" " " motor.
40,720	"	"	3	"	" " " overflow.
29,654	"	"	2	"	" estimated to consumers.
73,232	"	"	5	"	" the estimated loss in pump.
127,733	"	"	9	"	not accounted for.

DISCUSSION.

THE PRESIDENT. Mr. Brackett, I think you have had something to say heretofore on loss of water from leakage and other causes.

MR. BRACKETT. I think that might perhaps be a good reason why I should not have anything to say now, and I do not know that I have anything new to say on this subject. It has been one to which I have given considerable attention, but not for some two or three years. I should think that a loss of nine per cent, which Mr. Crandall reports, was somewhat less than has been observed in other cases. Of course in his case he had a comparatively short pipe system, and with a larger and possibly older system, I think the loss would be greater. In some cases I have known of, where almost all the water that was pumped was metered, the loss has been as high as thirty per cent. The difference is supposed to be due to leaky mains. Perhaps that statement had better be qualified by saying leakage from mains and loss from the meters. Of course we all know that meters that have been in service long enough will have a certain loss, so a portion of that thirty per cent should be charged to the loss through the meters.

MR. WHITNEY. I should like to ask Mr. Crandall how long those meters had been in use at the time he made the experiments?

MR. CRANDALL. Some of the meters had been in use ten or twelve years, but just prior to the commencement of the test every meter was overhauled and tested, and when the test began, they had within a month of that time, been found to register within the per cent named.

Mr. Richards. I would like to ask Mr. Crandall if the pump plunger always completed its stroke, if it made the entire stroke every time?

Mr. Crandall. I called attention to the fact that in the motor, as in some makes of meters, on small streams or slow velocities, there is a shortage in the stroke, which, in this case, I thought amounted to fully three per cent of the stroke, but that in practice we do not expect our motor runs much of the time with so short a stroke as that. I allowed three per cent as the loss on that one account, and the other two per cent was for ordinary losses through valves and leakage past the plunger.

Mr. Richards. I think there is no doubt but that there is a very considerable leakage in mains very often, not large in any one place, but very small in a great many places, and that the sum total amounts to a big figure. It often happens, as we all know, that there may be a big leakage in one place which we do not discover, yet I think the leakage comes mainly from very small joint leaks in a great many places.

The President. Mr. Kieran, can you give us some information in regard to loss of water in Fall River?

Mr. Kieran. Mr. President and gentlemen: I am sorry to say that our loss is much greater than Mr. Crandall's as far as we can get at it. During the past year we have been making some investigations, and we found that the loss was 40 per cent, that is taking the whole pumpage, and taking the whole supply for the town. We have one and not two systems (as I understand Mr. Crandall his experiment has been made on the high service) and it is most all metered. The greater part of our consumers are metered, and over 90 per cent of our revenue comes from the metered service. But our city is supplied for all public institutions and places free, and they use the water pretty freely too. This year I hope we shall be able to stop a great deal of it, for the reason that we have been metering the public places, schools and stables and the City Hall, watering troughs, parks, etc. Up to the first of the year we lost 41 per cent which we cannot account for. We made an estimate for the city stable based on what we have been receiving from a private stable, or a boarding stable, where we have had a meter set. We allowed the same amount, but on placing a meter there we found they were using over three times that amount, where there were no

carriages to wash, simply horses to water. We supposed that washing carriages would offset quite a waste, but we found it did not. The city stable with fifty-six horses has used over three times as much as was used in the boarding stable with seventy-five horses. I hope this season we shall be able to get at some of that waste, and possibly we can. We have taken our full rate consumers and have placed them on the same ratio with the metered takers; and for all stopped meters we find during the quarter, we make an estimate on the basis of the same quarter of the previous year, and call it the same number of feet.

Mr. Brackett. I would like to ask Mr. Kieran if the 40 per cent includes the whole use by the city? That is, whether the 60 per cent which you have measured or can account for is simply what is metered, and the 40 per cent includes all other uses?

Mr. Kieran. The 40 per cent is the actual loss, what we can not account for after estimating for public purposes. That is the actual loss.

Mr. Stacey. Perhaps some of that can be accounted for in the way we are trying to account for some of our water. For all our school buildings we get $6 a year. We came to the conclusion we would put on a meter at one of the schools, and the first three months it ran 21,000 cubic feet. We thought that was accounting for some of the water we could not account for otherwise.

Mr. Crandall. Speaking about accounting for water used for public purposes, I think I can add a pretty good story which is true. Our public buildings and parks committee decided on the 31st of July last that they were being overcharged at the schedule rates, and that they would in the future pay the meter rate. We had for the previous year, and for the previous months of last year, had meters on the park services for our own information, although they had paid the schedule rate during that time. On footing up at the close of the season, I found that for the months since the 31st of July when they were paying at meter rates, they had used about one-fourth as much water as they did during the preceding months of the same year; I mean, the rate per day was about one-fourth the rate during the preceding months, and the preceding months were the wet months of the season. They had used during the period for which they were paying meter rates about one-fifth what they used the preceding season; I am speaking of the rate

per day each time. We find it is very difficult to make the individual consumer understand why he should practice economy, when he sees water being wasted in public places at the rate I have just spoken of.

Mr. Holden. I would like to inquire of Mr. Crandall what the cost of this motor was, and how much the expense of keeping it in repair was.

Mr. Crandall. Our motor is a small one; it is for a 10-inch main. It was put in before I had anything to do with the water works, but if I remember rightly, it cost about $2,000. The cost for maintenance, that is the care of the machine, for no automatic machine will run without care, and the cost of repairs, charging it whatever gas is burned, and anything that is used at that place, has amounted to less than $400 per annum since I have been on the works. Mr. Richards has a much larger motor, and he probably remembers just what that cost.

Mr. Richards. Our motor is larger, and pumps more water. My recollection is that the motor cost about $5,000, and the cost of maintenance is about $300 a year.

Mr. Crandall. In my cost for maintenance I am including the proportionate part of the fuel that is used for pumping water at the low service. The motor runs in either direction. We can make it run by pumping water into the reservoir, or it will run when the pumps stop; without any action on our part, it will automatically reverse itself. Mr. Richards' motor only runs one way, there is no occasion for running it the other way. In our case, when the motor is run by the pump, there is five pounds additional pressure, and a certain per cent of fuel used at the low station is properly chargeable to the high station, but in the figures is included the per cent of fuel which would be used did the motor run all the time, which it does not.

Mr. Fuller. In Wellesley we meter all the water that is consumed, or attempt to, and I think during the month of December—if I had known this matter was coming up I would have looked it up a little more carefully—I think we accounted for 67 per cent of the water we supposed we had pumped. We do not meter the water as we pump it, as it goes into the mains, but I think in the spring we shall attempt to do that. This comparison is based on allowing, I think it is, 3 per cent slip on the pump, and using about

the full length of the stroke of the pump. I know we lose something by small leaks through the meters that is not recorded, but we have tested our pipe system and are sure that there are no large leaks there, probably there are some small leaks, and it seems to be quite a problem to account for this apparent discrepancy in the amount of water pumped and what is recorded.

Mr. Whitney. Isn't it probable, Mr. Crandall, that your low pressure on this section accounts for the very large percentage which you can seem to find of the water pumped? What I mean is, is it not probable that on a regular water system with heavy pressure, dribbling ball cocks, the water for which is not registered by the meters, oftentimes accounts for a very large percentage of this water which is lost?

Mr. Crandall. There is no doubt in my mind that an increase of the pressure would increase the amount unaccounted for.

LAYING A 24-INCH MAIN UNDER THE NASHUA RIVER.

BY HORACE G. HOLDEN, SUPT., NASHUA, N. H.

[*Read February 9, 1898.*]

The city of Nashua is located on both sides of the Nashua river near its junction with the Merrimack. It is fourteen miles above Lowell, and seventeen miles below Manchester. The entire water supply for domestic use, steam boilers and fire protection is furnished by the Pennichuck Water Works.

The water is taken from a system of ponds and reservoirs fed by springs and the Pennichuck brook about two miles north of the city, being pumped through two lines of cast iron pipe, 24-inch and 16-inch. These two lines unite near the center of the city into one 24-inch line, the whole length of the 24-inch pipe being about three miles.

In crossing the Nashua river the pipes are suspended under a "lattice bridge." Although the bridge has held the water pipes safely for forty-four years, an accident might at any time occur to the bridge; by which a large portion of the city would be left with a very limited supply of water. For this reason it was deemed advisable to lay a separate 24-inch pipe under the river and connect it with the main 24-inch near each end of the bridge, forming a loop, so that in case of any accident to the bridge the water supply could pass under the river, which at this point is about 250 feet wide, with an average depth of 18 feet.

Owing to difficulties about obtaining a right of way to the river, the crossing had to be made about 150 feet above the bridge, the submerged part requiring twenty-two lengths or 264 feet of pipe having the "Ward joint."

[A model of a "Ward joint" was here exhibited.]

You will notice by the model that the bell is larger and deeper than in the common joint, and that the inside of the bell is turned similiar to a hollow sphere, while the spigot has two ribs running

around the pipe. These ribs are seven-eighths of an inch less in diameter than the inside of the bell, so that after the lead is poured there will be seven-sixteenths of an inch of lead in the thinnest part of the joint, while the ribs serve to hold the lead in place and prevent the joint from pulling out.

The south bank of the river at this place had for many years been used as a dumping ground for the refuse from the neighboring factories. This necessitated the grading of the bank, starting about fifty feet from the edge of the river and sloping into the river for several feet, in order to prevent too great a bend in any one joint. The pipes were put together on the slope, being laid on rolls resting on plank. The first pipe used had an ordinary bell end, which was plugged tight. The other end of the pipe had a "Ward joint bell," and into this the spigot end of the next pipe was firmly leaded, about one hundred and fifty pounds of lead being required for each joint. As fast as the pipes were put together they were secured from pulling apart by a heavy cable lashed twice around each pipe, and six to eight empty oil barrels secured to these lashings to keep the pipe from sinking. Then with a windlass on the opposite bank the line of pipe was gradually drawn across, the rear of the line being held by snub lines which prevented the pipe from going to the river any faster than the joints were completed.

After the submerged part was finished and the pipe line stretched from shore to shore, being held up by 175 empty barrels, the pipe was then filled with water from a neighboring hydrant. This caused it to gradually settle, and upon cutting the lashings to the barrels in various places along the line, the pipe slowly sunk to the bottom of the river, and then the line was extended from both banks to the pipes on the main street near each end of the bridge.

The unusual spectacle of a 24-inch pipe line being lowered to the bottom of the Nashua river drew a large gathering of spectators, and the Nashua bridge was crowded with people watching the operation, among whom was the ever present newspaper correspondent, and the next day the Boston *Post's* "Observant Citizen," who evidently was not up to date on submerged pipe laying, broke loose as follows: "I was in Nashua yesterday and was much amused, while waiting for a train, by watching the rather primitive methods of a crew of workmen engaged in placing a water main across the bed of the Nashua river. Wishing to suspend the pipe

until the divers could arrange the supports under them, they employed empty barrels to float the pipes. Unfortunately the casks had been used for oil, and as soon as the weight of the pipe was applied, the ropes would slip from the barrels, sending them bobbing around in all directions. The current did not particularly facilitate the efforts of the disgusted workmen in reassembling them.''

The facts of the case were that the barrels were lashed to the pipes to lift them. When "Observant Citizen" saw the barrels, the diver was on the river bottom cutting the lashings and allowing them to escape. This was for the purpose of lowering the pipe to its place on the bed of the river. The work may have been primitive, but it accomplished the purpose for which it was intended, and the only workmen were the diver and his two assistants.

After setting 24-inch water gates at each end of the submerged line the street pressure, which at this place is about seventy pounds, was let on, and in order to test the line for any leaks two ⅝-inch corporation cocks were tapped into one of the pipes on the south bank of the river. A test gauge was placed on one of these cocks, and from the other a line of 1-inch pipe was laid and connected with a service pipe from a neighboring building. On this line was placed a ⅝-inch meter which had been carefully tested, also a force pump capable of raising the pressure to 100 pounds to the square inch. The first test showed a leakage of about two gallons per minute and on examination of the pipe line by a diver small leaks were found in several of the joints. These were then carefully caulked, and at the present time the leakage is greatly reduced—the last test showing about thirty gallons per hour. It is my intention next season to have the whole line perfectly tight.

The pipe for this job was furnished by the Warren Foundry & Machine Co. The work on the submerged portion was done by the well-known diver and contractor George W. Townsend of Boston.

DISCUSSION.

Mr. Crandall. I would like to ask Mr. Holden if there was any preparation of the bottom made for this pipe line, before it was lowered into position?

Mr. Holden. The bottom of the river was very smooth; there

were no stones of any amount, and there was a hard gravel bottom on the south shore. On the north shore was a little mud, so the pipe settled down. We didn't have to make any preparation whatever, and as the pipe lies, I had it examined by one of my own men with a diving suit; he found every pipe was well bedded on the bottom of the river.

THE PRESIDENT. Mr. Brackett, I think you have recently had some experience in laying pipe across or under rivers?

MR. BRACKETT. I think some of the other members, who have done the work, can perhaps, tell better about this work, than I. I think Mr. Gowing can tell you about one section which has been laid.

THE PRESIDENT. We would be very glad to hear from Mr. Gowing. Perhaps Mr. Brackett could tell us how it was proposed to do it and Mr. Gowing could tell us how it was done.

MR. GOWING. We laid a pipe across the Malden river, but the pipe laying part of it was not difficult at all, because we put in a coffer-dam and pumped it out dry, and then we laid the pipe just as if it were on dry land. Where that can be done, of course, it is very much better than any Ward joint, or anything of the sort, I think. It is a good deal more expensive, it would have been more expensive to have laid the pipe across the Nashua river in the way we laid it across the Malden river, than to lay it as it was laid. But I think the Metropolitan Water Board has one satisfaction for the money they spent, and that is they have got a tight line. I wasn't there when it was tested, but they told me that the meter refused to work, and I don't believe they will ever have any trouble and if they get 10, 20 or 30 per cent loss, it won't be on our line.

MR. BRACKETT. We have laid three large lines of pipe across rivers, but I do not think at the present time I can give you full details of the work. If it would be of interest, I might tell you in a general way how the work has been done.

In crossing the Malden river, of which Mr. Gowing speaks, we considered that it was better to lay the pipe by means of a coffer-dam than it was to use flexible joints and lower the pipe into a dredged trench. It may be, perhaps, that there were peculiar circumstances in this case.

We had two crossings of the Charles river and one of the Mystic river. One of those on the Charles was about 600 feet in length, the other about 400 feet, and the one on the Mystic was 1,200 feet.

They are all in connection with 48-inch pipe lines, and we have used a double 36-inch pipe line at each river crossing, to prevent the entire loss of the main in case of any leak on one of the lines crossing the river, and also for convenience in doing the work. The pipes which have been used, the pipe being laid in salt water, have been made very heavy; the 36-inch pipe is 1.65 inches in thickness, and weigh 677 pounds per foot, which is very much heavier than is used even for 48-inch pipe.

There were three types of joint used on the lines. One is the ordinary joint, with the exception that in place of one lead score there were three, for more firmly holding the lead.

The second type had a turned spigot end, with a very slight taper, about a sixteenth of an inch in five inches. And in the socket or bell of the connecting pipe the lead was cast, and then the spigot end was withdrawn and jointed under water afterward.

The third type was a ball and socket joint similar to the Ward joint, the difference being that the lead is cast into the bell rather than being cast on to the spigot, so that when the joint turns the lead is not drawn out of the bell. Flexible joints were only used at changes in the vertical line of the pipe.

The pipes were made up on the shore in sections, generally of six lengths of pipe, and at one end of each section was a turned tapered spigot, the bell at the other end having the lead cast in to receive the spigot end of a section which had already been laid. The whole section was suspended on a truss hung from derricks on a scow, and then lowered into position, in a dredged trench in the river. The diver entered the spigot end of the tapered pipe into the bell, or into a guide which was bolted to the bell end of the pipe which was being lowered, and then by hydraulic power, applied through a cylinder and piston attached to the truss, the pipes were drawn together, and they were afterwards caulked by a diver. That is in general the method in which the work has been done.

At the crossing of the Mystic river, the entire length of 1,200 feet of pipes were laid on a pile foundation, consisting of a 10x10 cap placed crosswise of the line of pipe back of the bell of each length, and supported by two spruce piles. On the other lines the pipes rest in the earth for the greater part of the distance, but are on piles near the shore where there was a soft bottom.

Mr. Winslow. Weren't those bottoms prepared for the pipes

independently of the piling, so as to carry them below the bottom of the river, so they were covered with earth?

MR. BRACKETT. The pipes were all laid in dredged channels, and were afterwards covered, so that they are below the bed of the river and not liable to be damaged by any vessels even grounding on them.

MR. HOLDEN. What amount of leakage do you get on your submerged pipe in the Charles river?

MR. BRACKETT. I stated I could not give you all the details. I know there has been some leakage, but I haven't the figures. However, they are reasonably tight.

MR. HOLDEN. In making out the contract for laying the pipe, of which I have spoken, I used the same specifications that Mr. Brackett used on the Charles river pipe—that is, that the leakage should not be over a tenth of a gallon per running foot per hour, which in our case would be 26.4 gallons per hour. At present the leakage does not amount to any more than that; it is just about that now.

MR. GILBERT. I might relate a little experience I had with laying a 12-inch pipe in the water some ten years ago. I wanted to lay it about 100 feet into a pond, so as to get the end of the pipe out into deep water. I made arrangements for putting it together on shore, and then shoving it out. I made preparations by getting oil barrels, making a number of rafts, etc., and got everything in readiness. We got the pipe started out into the water, and attached the oil barrels, and as we put in a piece of pipe we would shove it out. It worked nicely, and I was very much pleased with our success, as I had anticipated a great deal of trouble in keeping the pipe on top of the water. We had the end of the pipe plugged up tight, and after getting it out about 100 feet, we got on to the rafts and cut loose our oil barrels. After we cut the oil barrels all away, and got the rafts out, our pipe still laid on the top of the water, and we couldn't sink it, it wouldn't go down anyway. Finally we knocked the plug out of the end, and the pipe slowly sank to the bottom.

THE PRESIDENT. I am told that Mr. Crandall has had considerable experience in laying pipe under water.

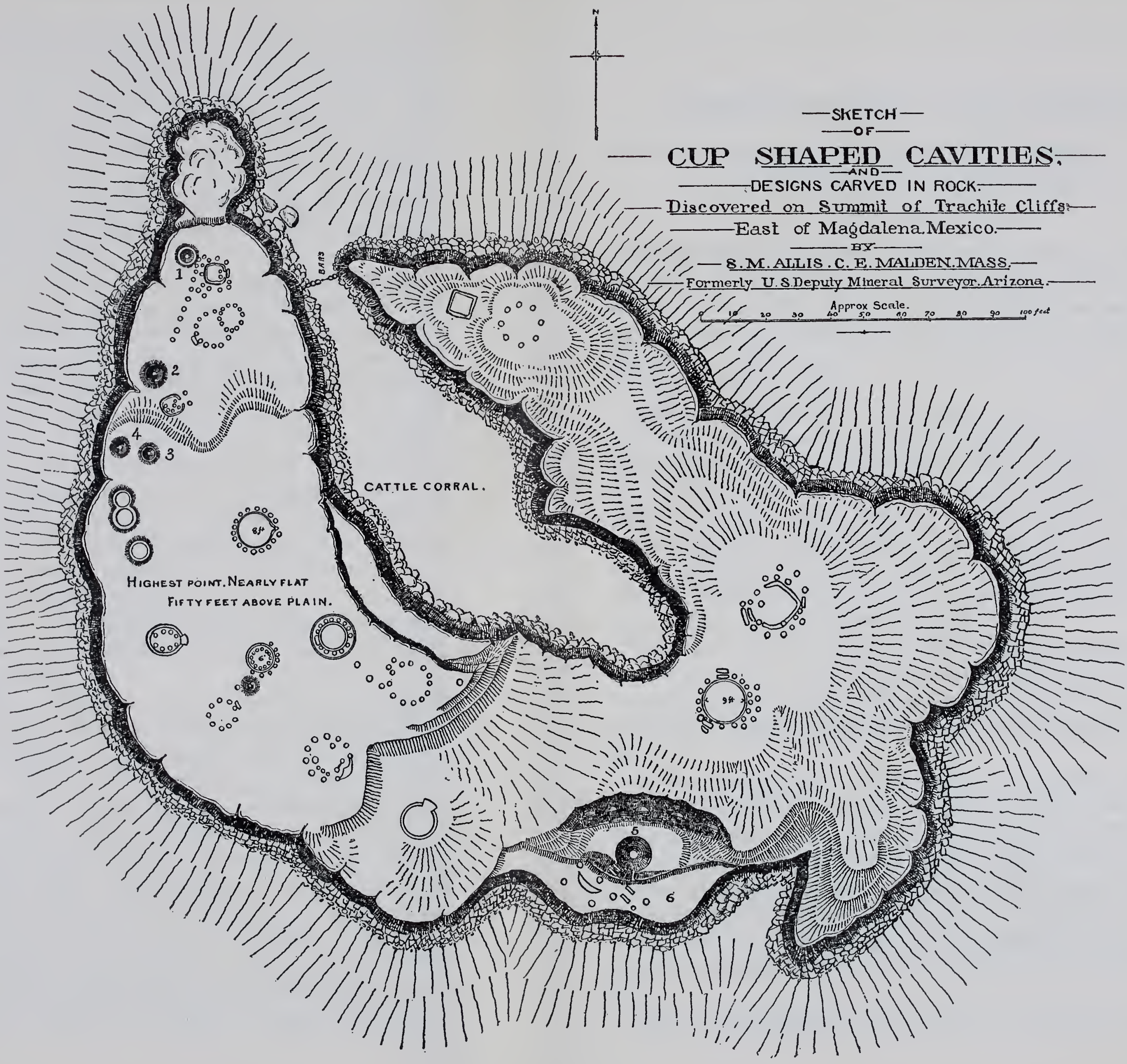
MR. CRANDALL. We laid about three miles of 24-inch on the bottom of Lake Champlain, in 1894. Mr. Falcon of Evanston, Illinois, had the contract, being the lowest bidder, and we used one

of his patent joints on every six lengths. I think he could have laid 600 feet a day if he had wished to ; but he did not want our citizens to know he had such a snap, I think, so he did not work quite as fast as that. The bottom of the lake is sand for the entire distance, overlaid with a more or less thin layer of mud, and experiments indicated that the pipe would settle through the mud on to the sand ; and in lowering the pipe it was found that it did immediately reach a bed. And at the time of laying the last lengths, which was several months after the laying of the first, the first lengths had not settled any from their first position.

There were two summits in the three miles, and openings were left at those summits, by tapping a brass tube into the top of the 24-inch pipe at as near the summit as we could get it, and tapping small holes through the brass tube. If I remember rightly, there are four one-eighth inch holes through the brass tube at each of the summits. The conduit when completed was tested by filling with water under 20 pounds pressure. I do not remember just what we specified for leakage, but the contractor was inside the limit. Since then tests have been made which showed that the leakage was diminishing. It was tested in 1895 and in 1896, and in 1895 the result was better than in 1894, and in 1896 it was better than in 1895. And when I say "better" I simply mean better; I do not mean to say very much better, but it was not worse.

Mr. Whitney. I would like to ask Mr. Crandall how the joint he used, the flexible joint, differs from this Ward joint which has been shown here today?

Mr. Crandall. The Falcon joint on the spigot end is spherical, and the bell end has a flanged cup into which this sphere projects, and there is a ring which it is necessary to slip on over the back side of the spigot. It will not pull over the turned sphere of the spigot even with no lead in. After slipping it over the spigot from the back side it is leaded. Then the flange on the ring is bolted to the flange of the bell, which is leaded to the other length to which it is to be joined under water. The joint made under water is a flange joint. In our case, which was a 24-inch pipe, if I remember rightly, there were twenty-six bolts, and, I think Mr. Falcon did the tightening up of the twenty-six bolts in a little less than twenty-six minutes. I went down afterwards to see if he had done it, on a bet, and I was unable to make it any tighter on any one of the bolts.


N
SKETCH
OF
CUP SHAPED CAVITIES,
AND
DESIGNS CARVED IN ROCK.
Discovered on Summit of Trachite Cliffs
East of Magdalena Mexico.
BY
S. M. ALLIS. C. E. MALDEN. MASS.
Formerly U.S. Deputy Mineral Surveyor. Arizona.
Approx Scale.
0 10 20 30 40 50 60 70 80 90 100 feet
BARS
CATTLE CORRAL.
HIGHEST POINT. NEARLY FLAT
FIFTY FEET ABOVE PLAIN.
1
2
3
4
5
6
8 ft
9 ft

EXPERIENCES IN THE "ARID SOUTHWEST."

BY SOLON M. ALLIS, C. E., MALDEN, MASS., FORMERLY U. S. DEPUTY MINERAL SURVEYOR, TUCSON, ARIZONA.

[*Read February 9, 1898.*]

Having spent some years mining and surveying in the extreme southwest of Uncle Sam's territories, and in Northern Sonora, Mexico, I was much impressed by the difficulties experienced in getting water for irrigation, and in many places for camp use. This difficulty is mainly caused by the physical features of the country which I will briefly notice.

Although Arizona has in its northern area an extreme elevation of 6,000 feet above the sea and mountain ranges that originate never failing streams of good size, such as the Gila and Salt rivers, yet we find a very large area in the southwest where the low lying plains rise from 12 feet above the sea at Yuma, to 2,500 feet at Tucson, distant 220 miles south of east. These low lying plains are diversified by small detached mountain peaks and ranges of no great altitude, but of forbidding aspect, as bare and rocky they glisten in the terrific heat of the summer months.

These give rise to different drainage areas, and the dry "arroyos," devoid of water during a large portion of the year, become in the wet season full of water, which sometimes comes from cloud bursts, resulting in raging torrents, generally, however, of very short duration.

On the eastern portion of this large area, and where the elevation becomes 10,000 feet and upwards, some of the streams have water the year round, as, for instance, the San Pedro which flows northerly into the Gila, its valley being east of the Whetstone mountains. Others disappear for miles, soon after the rains cease, and are only found flowing continuously at intervals. Among the latter is the Santa Cruz, which, rising in Arizona, runs south into Sonora, then turning west and north, returns to Arizona and empties into the Gila.

This river disappears near the line as it reenters Arizona and

reappears above Tubac, about twelve miles north of the line, and remains at the surface several miles, then it sinks out of sight and comes to the surface at a point about forty miles distant and about eight miles south of Tucson, not far from the old church of San Xavier, built over 100 years ago for the Papago Indians, upon the site of another that had stood 150 years. It now appears for about sixteen miles, and about eight miles north of Tucson again disappears for ninety miles, being found 150 feet below the surface about fifteen miles north of Tucson.

The reason of this eccentric action is found in the fact that the valley of the Santa Cruz, everywhere wide and quick sloping, is composed of coarse gravels, which being nearly destitute of clay, permits the water to seek a lower level until it flows along the bed rock. At Tubac and Tucson a series of trap dikes across the valley, nearly at right angles to the stream, making a natural dam that brings the water to the surface. This accounts for the fact that Tucson has been for years an oasis in the desert, and was a permanently settled town of Pima Indians, when first visited by Coronado in 1539.

Below Tucson, where the river commences to sink, the farmers dig long ditches, graded slightly as possible, and bring the water out of the lower country for quite a distance. Adopting this hint from nature, a number of California companies have secured good supplies by digging deep trenches across the narrow valleys or canyons to bed-rock, then building a tight wall of masonry therein, thus bringing the subterranean supply to the surface.

When I first went to Arizona, I found it to be the opinion of the settlers that water must be searched for by digging down to the underground stream in the middle of the valley, as was the custom and is now by the Mexicans.

Many fine grazing tracts were unoccupied for want of water, especially upon the foot hills, where the best gramma grass was found and generally much desired shade. Some one thought of testing the slope near the foot of the mountains, and plentiful supplies were thus found in many places, of course depending as every where else upon the water shed above.

The Southern Pacific Railroad Company have experimented with artesian wells and, while some have been failures, enough have been successful to warrant attempts all along the line.

The great Sulphur Spring Valley, sixty miles wide, and shunned

by prospectors and travelers on account of its dearth of water, has been found to have plenty of water almost everywhere, from 30 to 40 feet below the surface, and within a few years the great Pierce mine was found in this valley This mine was bought by Senator Penrose for $60,000, and is no producing $450,000 per month.

While developing some mining property west of Querobabi, on the Sonora railroad, and about ninety miles below the boundary line, I found an extreme scarcity of water. The mines were inside an elevated rim of low hills, some nine miles from the station, and about 500 feet higher.

The railroad was located at the lowest point of the wide valley and near a dry arroyo. The Mexicans had dug a well near the depot 300 feet deep, without getting water, and the attempt was abandoned. To supply their employees, the railroad company sent water in large iron tanks from a point some thirty miles distant. For some time I purchased from four to six barrels a day for camp use, paying two cents a gallon, and hauling all the way up hill to the camp over a sandy road. After some study of the surroundings, I determined to sink a well, although the Mexicans laughed at the idea. Selecting a point quite near the arroyo where it debouched from the circle of hills, I sunk a shaft four feet by five feet, blasting through porphyry all the way, until I reached a point ninety-two feet below the surface, when the water which had begun to come in at seventy feet in small quantities, now came in so fast I went no farther, and the next day we had ten feet of fine water. When the rainy season came my well had seventy-two feet of water in it and was the wonder of the Mexicans. The main road, in use for more than a century, was changed so that travelers could camp at my well, and "Allis Pozo" is in use today and the only well of its kind for hundreds of miles. I would say here that when the Mexicans dig such deep wells in the valleys as I have mentioned (and I have seen many from one to two hundred feet deep), the soil is so firm that no curbing is needed.

A rude windlass is erected over the well rigged with a grooved wheel about eighteen inches in diameter, made of wood, over which a raw hide rope is passed. At one end a bucket made of rawhide, holding about half as much as a flour barrel is fastened, and the other end tied around the horns of a steer, which thus makes a primitive hoisting machine, used also to hoist the water

when the well is completed. The Papago Indians who inhabit the driest portions of Arizona and Sonora have another way of procuring, or I might say, saving water on these arid plains. Selecting a place where the slope is pronounced, they dig long trenches or throw up a ridge of earth diverting from the lowest point at an angle of forty-five or sixty degrees. At the lowest point where the water is collected the earth is thrown up from both sides, making in some cases a dam four or five feet high. The inside is carefully plastered with wet adobe soil, making a small pond. The heavy rains (if they happen to have any that season) fill these ponds, and this supplies them sometimes until quite well along into the dry season. When this is exhausted they migrate as usual to springs in the mountains, known to them, where they remain until the next wet season. As the Indians and the herds use out of the same pond, no pains being taken to keep the cattle from wading in it, the condition of the water when nearly exhausted can better be imagined than described, and I am afraid would lead to a remonstrance from the Massachusetts Board of Health, if they ever saw it.

Myself and a companion, named John McDonald, once lost our way in the Papago country, while attempting to find a mine near the Mexican border. We were out of water and nearly choked, when at dark we stumbled on to one of these abandoned rancheros. By carefully exploring the deep holes in the clay, made by the feet of the cattle, we found about two quarts of water from a late shower. This we strained two or three times and made some coffee, putting in a good deal of sugar. It came the nearest to some of my war experiences in the swamps of North Carolina of anything I ever met since in the way of bad water. Our horses had to go without and we traveled twenty miles the next day before we found water.

Starting out one morning from Nacosari canyon, in eastern Sonora, and among the foot-hills of the Sierra Madre, a party of us searched for many miles for an old abandoned mine of the ancient days.

I carried a canteen holding two gallons of water, but by noon it was all gone, as I had a bad attack of fever and ague, and I had shared with another member of our party. The sun was blazing hot, and by 4 o'clock we were all out of water, and pretty well used up, and turned towards camp.

Crossing a steep, high hill, we saw in the valley two large, green trees said to be mountain mahogany. One of the Mexicans said we would surely find water there. Our mules seemed very willing to go all at once, and we soon reached the place. I found under the trees, which were near a high ledge of rock, two tanks as they are called, being deep holes in the rocks about four feet in diameter and nearly the same depth, which had been filled by the rains of many weeks previous. The top of the water was covered with a thick, green scum. On dipping this out, the water seemed alive with black bugs resembling our beetles. I slapped the surface with a quart cup which caused them to scuttle away, and taking a drink, I found the water perfectly pure, and it seemed to taste as well as any I ever drank. It was accidentally finding some tanks like these on the desert west of Tucson that saved the lives of the men under General Kearney, who marched from Santa Fe to Los Angeles at the time we first occupied California.

As I intimated when I began, I might tell you some experiences not exactly in the line of superintending water works, and if I have not already exhausted your patience, I will give you in closing an experience I had in looking up some curious rock sculpture, by some ancient dwellers in Sonora.

While engaged in opening the Sonora mines, I was also developing some property in the Sonoita valley, about twenty miles north of Nogales, a small town on the railroad, where it crosses the boundary line. Thus I was obliged to make frequent trips over this railroad, which connects Guaymas with Benson and Tucson, Arizona.

While in Tucson, on one of these trips, I met a gentleman who had been looking for coal in Sonora. He informed me that while examining the country southeast of Magdalena, he had came across what he called the "Indian rock sculpture," about sixteen miles distant. He described rooms cut in the rock, grapes in bunches carved on snow white walls and circular projections smoothly carved and beautiful to behold. All this so excited my curiosity that I determined to visit the place at the first opportunity.

This did not occur until March, 1883. I had met at Magdalena a Mr. Wells, who had accompanied my informant on his coal hunting expedition. I had arranged with him to be my guide whenever I could stop off, and on March 21 I left the mines at Querobabi, for the station, arriving there about dark. Before leaving camp, I

was informed that a large band of Apaches, lurking in the Sierra Madres, had made a descent near Carbo, a town some twenty miles south, and were driving off all the cattle they could gather. Some of my men were quite alarmed, and feared our camp might be attacked. I assured them that there was no danger, as I had never known the Apaches to cross the railroad, and we were nine miles west. On reaching the station I found a special train with Mr. Seeley, the superintendent, the chief engineer and Mr. Hunt, the paymaster, on their regular trip to pay off, and I went to Magdalena with them. Our train had barely left the station, when as I afterwards learned, several men bringing silver from the San Augustine mine, situated some twenty miles east, were fired upon by a party of Apaches, hidden in the bushes a mile from the station. The men reached the station, with no casualties except wounding one of the mules.

Arriving at Magdelena about 9 o'clock, I went to the hotel and there found Wells, and arranged for an early start. Daylight found us on our way each on a good horse and well armed. Our way for the first eight miles followed the road over a high and rugged mesa, covered by prickly pear and giant cactus. After leaving the valley, where the abundant streams of water had made the existence of a town possible, the country assumed a forbidding aspect. Sage brush, mesquite and an occasional palo verde were the only vegetation, while tall crosses or large heaps of stones marked no less than seven graves of travelers, killed by the Indians, within as many miles.

One of the saddest scenes in Arizona and Sonora is the solitary grave found here and there all over the country, marking the spot where some lonely traveler or wandering prospector has fallen a victim to the murderous Apache. In southern Arizona it is said over eight hundred such graves dot the wayside.

Eight miles from Magdalena we left the road, taking a blind trail for eight miles more, leading over low ranges and a rugged country almost destitute of vegetation, to our destination. We found ourselves about 11 o'clock in a wide, grassy valley, enclosed by high hills, behind which towered the Sierra Madres which form the backbone of Sonora. A small brook running down through the valley and the green grass bordering it looked very pleasant after the tedious ride of the forenoon.

Here we found the first carvings, which instead of having been made by Indians were unmistakably wind carvings. Some of them were so beautiful and curious that I was not surprised that they had been supposed to be of human origin. The view for a long distance up the wide valley was unobstructed, except by a few detached cliffs of white trachite. The upper surface of these cliffs was of a much harder texture than that immediately below, as if the surface of melted outflow had been hardened by the air, and some of the cliffs were harder clear through than others. The upper layers were of a brown color, while the portions below, which had been worked out by the wind was as white as snow. The texture of the underlying rocks in the softer cliffs was somewhat harder than chalk, while imbedded were thousands of sharp edged grains of quartz, which becoming loosened were blown about by the wind, adding their cutting qualities to the erosive action of the windborne dust.

In some of the cliffs the rock was cut out in a beautiful manner, leaving a projecting roof hollowed out and as smooth as if cut by a skillful artist. In others, hard, concretionary substances stood out in relief, resembling a bunch of grapes. These after awhile becoming detatched, fall to the bottom of the cliff, covering the ground. These concretions were flint like and round, varying in size from that of a bullet to that of a butternut, and so hard that when placed upon an anvil, a severe blow with a sledge would hardly crack them.

In one of the cliffs the projections had been taken advantage of by three herders from Magdalena, who were taking care of a bunch of cattle feeding in the valley. A wall of boulders was built under the edge of the projecting rock, making a comfortable room eight feet wide and high and about twenty feet long.* The shape of one of the larger cliffs, shown in plan and elevation, was such that a large and secure enclosure was made by putting up a pair of bars, and it was used as a corral for the cattle. We made some examinations and picked up a few of the "grapes" of stone already described, before dinner.

After feeding our horses and taking our lunch, I suggested that we climb to the top of the highest cliff, about 40 feet. This we

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*Mr. Allis distributed drawings and sketches illustrating these wind carvings and cup-shaped carvings mentioned farther on.—Ed.

did, not without considerable effort. There we found on the hard surface of the smooth, gently rounded slopes and flat places, another and quite a different kind of carving, evidently made by human hands. To my companion, these were quite as new as to myself, and I can find no evidence that they were ever noticed earlier than at our visit.

These carvings were cup-shaped, with curious channels in some places taking the place of the cups. The channels were mostly about four inches deep, and about as wide, but a few were somewhat larger. As will be noticed on the larger sketch, the circular rows of holes were in some cases enclosed by the channels, in others the reverse, while still other designs are channels without the cups. These channels were generally V shaped, although some were hollowed out more like the letter U.

Near the upper left hand corner of the sketch are seen four projections of solid rock, standing nearly two feet above the level of the cliff, each with a deep, well-carved hole in the summit about eight inches in diameter and about the same in depth. These holes were black with age, apparently, though fire may have done this.

On a shelf or bench of rock and some four or five feet below the top of the cliff, on which the cups were carved, was found what seemed to be a cistern, about eight feet in diameter and about four feet in depth, cut beautifully round, reminding one of the pot holes found in the rocks below the water-falls of many of our New England rivers. That this was a cistern seemed to be indicated not only by its position and evident human workmanship, but also by a narrow channel cut from its edge at top to the edge of the cliff, so that if it filled with water it would flow to a second bench below, where again we found cup and other carving, one of which resembled a crescent. In the side of the upper bench above the cisterns were found five cavities hollowed out, some eighteen inches or two feet long and nearly as deep. These seemed to have been designed as places of deposit for small articles.

I was much puzzled to account for these carvings, and on my return to Tucson mentioned them to Dr. J. C. Handy. He had a short time previously received a book by Charles Rau, published by the Smithsonian Institute, in 1882, describing the cup-carvings of Europe and Asia, which he showed me, and I at once saw that the Sonora carvings were of the same character as those the book de-

scribed. These carvings are so similar to those found at the Temple of Chandelahar, India, that I think we may without mistake assign them to the same origin, namely, emblems of the Phallic worship of the ancient Aryans of India. No cup-carvings like those found in Europe and Asia, except the scrolls designated as type 7 in his book, seem to have been known to Rau, as existing in this country, and those found on a large boulder in Santa Barbara county, California, and the latter he called mortar cavities. Detached holes of the Santa Barbara character are common and generally supposed to be corn-mills or mortars, and are much larger than the cup-carvings, generally eight inches in diameter and as deep.

In southern Arizona, the Initial monument of the Barba-comori grant surveyed by myself in 1882, is built around a post set in one of these corn-mortars, found on the summit of a magnetic rock, on the edge of a cienaga at the center of the grant. I observed a row of these corn-mill holes under a large projecting rock, a few miles south of Tucson, Arizona, where evidently the families of the Indians collected in the shade to pound their corn. From this point a fine view was had of the valley of the Santa Cruz river. These holes were all large and in the hardest rock.

The conclusion as indicated, if correct, throws another ray of light upon the vexed question of who first settled the Western Hemisphere, and points to a race far antedating the Aztecs or Toltecs, whom Cortez found already an ancient race of people in Mexico.

We were fortunate in selecting the day of our visit, for on the day following the same band of Apaches, spoken of as being at Querobabi, reached this place and the three herders were all killed, as was also the owner of the cattle, who, unfortunately, went there the same day.

FIRE PROTECTION, BY WHOM AND HOW IT SHOULD BE PAID?*

BY JOEL FOSTER, SUPERINTENDENT, MONTPELIER, VT.

If a private corporation owns the franchise of a water system in a village or city, it is universally understood at the outset that the village or city is to pay a stipulated price for hydrants, watering troughs, stand pipes for sprinkling streets, flushing sewers and for public buildings. These expenses would be paid by an increase tax on the grand list, and who claims that it would not be just and right?

On the other hand, the village or city owns its water system. Is there any reason why an appropriation from that village or city, equal to the sum paid to the private company for the same benefits received, should not be made? On a careful investigation of this question I believe that every considerate person would answer, No.

It is universally conceded by all engineers and contractors of water works that the cost to construct for a good fire protection is fully one-third more than is necessary for domestic and sanitary purposes. Then why not have the property protected bear its due proportion of the burden of expense, instead of wringing it out of the patrons of the city water? We often hear the remark, "The water works will pay for themselves; why make the appropriation? It is only taking money from one pocket and putting it into the other." Is this assertion true?

In making no appropriation for the hydrants and other public uses, and relying wholly on the domestic and business receipts of the water works to pay their cost and expenses, who pays for fire protection and the other luxuries named? I will try to give figures below that will demonstrate the facts.

*From the Annual Report, Montpelier, Vt., Feb., 1898.

There was printed in the city papers last year a statement giving the total grand list of the city in 1897 ($38,004.89), and the lists of individuals.

The grand list of taxpayers having a list of $100 and over aggregated	$16,096.10
Over $50 and under $100	6,982.15
Less than $50	14,926.64
The water receipts for the business year were	11,313.86
Of this sum I find that the division of the taxpayers having a grand list of $16,096.10, paid for water service	2,820.00
The second division, $6,982.15, paid for water service	1,676.50
The third division, $14,926.64, paid for water service	6,817.36

To tax these several divisions of the grand list, as shown above, on the basis of their contributions to the gross water receipts ($11,-313.00), the percentage assessed to each division would be as follows :

Taxpayers having a grand list exceeding $100	$0.175	on the dollar
Taxpayers having $50 and less than $100	.24	" "
Taxpayers having less than $50	.45	" "

which shows at a glance the unjust discrimination of the taxation to the varied owners of city property.

To illustrate further the inequality of paying for fire protection and other public uses of city water by throwing the whole burden of such expenses on to private consumers of water, I will take the case of individuals.

The water system asks the city of Montpelier to appropriate $2,300.00 a year for hydrants, watering troughs, stand pipes, etc.

This sum was voted at the annual village meeting December 5, 1887, and was paid over to the water system annually till 1896. The city council then refused to make the appropriation, compelling

the private users of the city water to bear the entire expense for public uses.

Under this new policy, I find by computation that the percentage paid by the division of taxpayers, whose grand list is $16,096, is 3.6 per cent., or................................$	579.45
That those whose grand list aggregates $6,982, is 5 per cent., or......	349.10
That those whose grand list aggregates $14,-926, is 9.15 per cent., or...	1,365.73
Loss by omitting fractions..........	5.72
	$ 2,300.00

That is, the division of taxpayers whose grand list is $100 or over pays for fire protection 3.6 per cent. of their grand list.

Those whose grand list is less than $100 and over $50 pay 5 per cent. of their grand list.

Those whose grand list is $50 and under pay 9.15 per cent. of their grand list.

This is a very unequal taxation.

The inequality of taxation for fire protection under the new policy of the city is further shown thus:

Mr. A. has a grand list of $200, pays $12 water tax.

Mr. B. has a grand list of $20, pays $12 water tax.

By this showing Mr. A., with his grand list of $200, contributes no more to the general receipts than Mr. B., with only a $20 grand list.

Is there any reason or justice in this division? Why should not Mr. A., with his $200 grand list, pay more for his fire protection than Mr. B., with only a grand list of $20?

The conclusion of the whole matter is, that putting the estimated cost of water for fire protection and other public uses into the regular expenses of the city, to be paid, like every other expense, on the grand list, is the only way to equalize taxation for the purposes named.

STATISTICS

FOR THE YEARS

1895 and 1896.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

Compiled by the Editors.

1895—I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Con'uction.	By whom Owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass...	1873	Town.	Well near Seven Mile River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich....	1872	City.	Lake Huron.	Direct Pumping.	Holly.	Bituminous.		
3	Brockton, Mass....	1880	City.	Storage Reservoir	Pump to S. P.	Worthington.	Bituminous.	8.44	4.74
4	Burlington, Vt.....	1867-8	City.	Lake Champlain.	Pumping.	Worthington.	Anth. Mill S.		4.65-4.78
5	Concord, N. H	1872	City.	Penacook Lake.	Gravity and Pump to R.				
6	Fall River, Mass..	1874	City.	Watuppa Lake.	Pump to S. P. and Tanks.	Worthington & Davidson.	Bituminous.		
7	Fitchburg, Mass...	1871-2	City.	Storage Reservoirs.	Gravitation.				
8	Lynn, Mass......	1872	City.	Storage Reservoirs.	Pump to R.	Morris & Loretz.	Bituminous.		4.55-4.62
9	Middleboro, Mass.	1885	F.Dist	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.75-4.50
10	New Bedford, Mass	1866-69	City.	Storage Reservoir.	Gravity and Pumped to R.	Quintard and Worthington	Bit. & Anthracite.	12.16	4.20-4.50 4.12-4.19
11	New London, Conn	1872	City.	Lake Konomoc.	Gravity and Pump to T.	(Water Motor.)			
12	Newton, Mass	1876	City.	Filter Basin and Driven Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.15
13	Oberlin, Ohio.....	1887	Vil'ge.	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.24-2.35
14	Plymouth, Mass...	1855	Town.	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.25
15	Reading, Mass...	1890-1	Town.	Filter Gallery.	Pump to S. P.	Geo. F. Blake.	Bituminous.		5.00-4.90
16	Springfield, Mass..	1873-5	City.	Impounding Reservoirs.	Gravitation.				
17	Taunton, Mass....	1876	City.	Elders Pond.	Gravity and D. Pumping.	Holly & Allis.	Bituminous.	3-7	3.60-4.00
18	Waltham, Mass....	1895	City.	Filter Basin.	Pump to R.	Worthington.	Bituminous.	11.00	
19	Woonsocket, R. I.	1884	City.	Crooks Falls Brook	Pump to R.	Worthing'n & Deane	Bituminous.	6.32	4.35
20	Yonkers, N. Y....	1874	City.	Grassy Sprain Brook.	Pump to R. & S. P	Wright & Worthington.	Anthracite.	12.25	4.34

1895—I. GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood. 3.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr Mil Gal. r'sd 1 ft high Fig on Total main'ance
1	465,993	1,000	466,993	109,808,840	160	175&188	236	36,900,000	$17.40	.0927	153.50	.817
2	3,220,140	49,329	3,269,469	1,122,363,460		113			6.73	.0595	43.82	.3871
3	505,185	225	505,410	400,974,405		43	793.7	28,451,641	7.40	.172	87.60	2.03
4				324,158,575	289	316			27.50	.087	141.53	.447
6	3,769,920			1,155,775,756		186			11.66		119.67	
8	436,500 1,723,799	222	436,500 1,724,465	344,707,090 1,251,053,100		160.68 160.47	789.7 725.5	105,826,355 97,091,511	5.88	3.66	76.65	.477
9	456,580		456,580	77,833,000	180	201	170.58	28,571,637	34.93	.174	89.47	.445
10	2,373,000	371	2,373,371	1,707,559,266	125.4 125.1 to 125.6	127.7 126.4 to 134.9	658 520 807	74,007,887 54,770,422 85,972,256	6.93	.530	40.93	.31 $\frac{34}{100}$
12	1,813,900	10,000	1,823,900	662,307,000	234	258	363	107,000,000	10.10	.039	156.3	.61
13	298,930		298,930	27,998,000	80	80	93.7	6,249,000	43.97	.55	164.20	2.05
14	2,181,600		2,181,600	103,118,400	65	66	471.72	25,965,355	14 55	.223	90.97	1.38
15	388,023		388,023	72,375,448	219	240	186.7	37,592,023	35.50	.147	178.51	.743
17	1,029,650		1,029,650	419,162,504		77.4	586.16	37,837,519	12.04	.155	163.55	2.11
18	1,648,900		1,648,900	445,972,320	164	190	271	43,084,870	19.92	.105	101.36	.53
19	872,477	317	872,787	225,587,860	238.4	239.5	258	52,248,733	15.15	.063	126.82	.53
20			4,230,266	1,166,751,521	185		276		11.38			

1895.—II.—FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
		$	$	$	$	$
1	Attleboro, Mass			14,188.00		
2	Bay City, Mich	17,514.55	4,891.76	22,406.31	413.99	22,820.30
3	Brockton, Mass			43,768.26	100.00	43,868.26
4	Burlington, Vt	34,161.77	5,431.62	39,593.39	3,161.57	42,754.96
5	Concord, N. H			55,239.77		
6	Fall River, Mass			117,130.47	326.00	117.456.47
7	Fitchburg, Mass	46,214.36	14,334.33	60,548.69		
8	Lynn, Mass	135,906.71	44,306.80	180,213,51	5,359.37	185,572.88
9	Middleboro, Mass	7,451.80	3,204.14	10,655.94	40.92	10,696.86
10	New Bedford, Mass	79,148.69	7,001.36	86,150.05	120.00	86,270.05
11	New London, Conn			38,634.05		38,634.05
12	Newton, Mass	74,149.31	7,800.00	81,949.31	4,016.08	85,965.39
13	Oberlin, Ohio	3,408.52	435.45	3,843.97	167.00	4,010.97
14	Plymouth, Mass	17,038.44	676.00	17,714.44	519,86	18,234.30
15	Reading, Mass	6,575.39	121.98	6,697.37	103.99	6,801.36
16	Springfield, Mass			173,840.65	33,448.40	207,289.05
17	Taunton, Mass	37,251.47	11,770.09	49,021.56	432.10	49,453.66
18	Waltham, Mass	49,870.21	5,667.16	55,537.37	4,531.35	
19	Woonsocket, R. I	26,868.02	7,562.38	34,430.40	101.21	34,531.61
20	Yonkers, N. Y	76,504.46	30,661.15	107,165.71	3,659.05	110,824.76

1895.—II.—FINANCIAL.—Continued.

Number.	Receipts from Public Funds. F Hydrants.	G Fountains.	H Street Watering.	I Public Buildings.	J General Appropriation or Miscellaneous.	K Gross Receipts.	AA Management and Repairs.	BB Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	6,800	300.00		$ 225.00	$ 7,325.00	$ 21,513.00	$ 6,434.28	$ 10,400.00	$	$ 16,834.28
2					27,110.00	49,930.30	22,067.64	27,110.00		49,177.64
3	3,000.00					46,868.26	8,826.30	26,300.00		35,126.30
4	6,140.00		1,509.00	270.00	500.00	51,173.96	34,503,43	11,375.00		45,878.43
5					530.76	55,570.53	3,445.85	27,150.00		30,595.85
6					35,000.00	152,456.47	50,147.83	100,704.99		150,852.82
7							18,298.58			33,693.36
8						185,572.88	51,147.43	71,182.67		122,330.10
9						12,696.86	4,189,14	2,774.50		4,189.14
10					25,600.00	111,870.05	34,295.39	35,600.00		69,895.39
11					24,540.00	63,174.05	6,709.22	24,540.00		31,249.22
12	14,600.00	991.60	2,550.00	983.40	995.00	106,085.39	16,020.25	87,500.00	4,148.28	107,668.53
13					2,873,23	6,884.20	1,897.15	2,700.45		4,597.60
14						18,234.30	5,105,59	4,276.00		5,105.59
15	3,300.00				3,900.00	14,001.36	4,919.74	8,000.00		4.919,74
16	15,860.00	1,850.75	4,580.50	3,910.30	25.000.00	259,405.60	18,478.33	97,750.00	3,552.18	119,971.67
17	3.500.00	2,063.89	800,00	521.73		75,076.00	20,550.06	48,003.00		68,553.06
18						59,968.72	29,119.70	16,186.65		45,306,35
19	14,372,50	1,205.70	1,873.80	919.87	10,447,68	63,351.16	10,554.95	18,054.90		28,609.85
20	16,290.00				2,636.07	127,114.76	34,763.60	71,083.33	6,968.37	112,815.30

1895.—III.—CONSUMPTION.

Number.	Name of City or Town.	1 Estimated Population. Total at Date.	2 Estimated Population. On Line of Pipe.	3 Estimated Population. Supplied at date.	5 Quantity used through Domestic Meters—Gals.	6 Quantity used through Man'f'tring Meters—Gals.	Percentage of Total Consumption Metered.	7 Average Daily Consumption, Gallons.	8 Gallons per Day. Each Inhabitant.	9 Gallons per Day. Each Consumer.	10 Gallons per Day. Each Tap.
1	Attleboro, Mass.....	8,300	6,800	6,300	109,808,840			306,357	36.2	48.7	
2	Bay City, Mich.....	33,000	20,000	14,000	53,088,095	51,033,957		3,074,968	93.0	219.0	1,661.0
3	Brockton, Mass.....	33,665	30,500	29,200	87,832,298	28,974,855		1,098,560	32.6	37.6	258.8
4	Burlington, Vt......	16,700	16,300	16,100	87,170,932	32,469,615	36.8	888,083	53.0	55.0	299.0
6	Fall River, Mass....	89,203		86,076				3,166,509	35.5	36.8	
7	Fitchburg, Mass....	26,500	23,000	20,300	58,157,000	286,000,000			94.0	123.0	670.0
8	Lynn, Mass.........	66,861			215,591,850			4,360,142		67.5	
9	Middleboro, Mass...	Town, 7,000 Fire D. 4,200	4,000	3,700				213,378	51.0	57.7	306.0
10	New Bedford Mass..	56,300	47,076	46,154	18,533,073	251,346,482	16.0	4,711,866	84.0	102.0	587.0
11	New London, Conn.	15,000	14,700	14,000	14,000,000			1,244,320	83.0	89.0	467.3
12	Newton, Mass.......	28,500	28,100	27,900	235,000,000	110,000,000	52.0	1,801,162	63.2	64.2	304.0
13	Oberlin, Ohio.......	4,500	3,500	1,900	4,361,070	2,157,000	23.3	76,700	17.0	40.0	173.0
15	Reading, Mass......	4,717	4,140	3,550	4,179,920	583,414		198,289	42.03	55.85	263.33
16	Springfield, Mass...	51,534	47,000	41,000	355,608,935		21.0	4,638,060	90.0	113.0	587.0
17	Taunton, Mass......	27,093	23,700	23,600	57,349,979	123,188,567		1,148,390	42.0	49.0	299.0
18	Waltham, Mass.. ..	21,000	20,400	20,000	28,120,950				58.5	61.9	402.0
19	Woonsocket, R. I...	28,500	26,000	23,500				621,464	21.8	26.4	336.0
20	Yonkers, N. Y.......	38,000	33,000	32,000	227,754,974	432,882,912	58.2	3,108,400	82.0	94.0	850.0

1895.—IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During Year, Feet.	4 Length Discontinued During Year, Feet.	5 Total Length in Use, Miles.	6 Cost of Repairs Per Mile.	7 Number of Leaks Per Mile.	8 Length of Pipe Less than 4" Diameter, Miles.	9 Hydrants. No. Added.	10 Hydrants. Total in Use.	11 Stop Cocks. No. Added.	12 Stop Cocks. Total in Use.	15 Range of Pressure Pounds.
1	Attleboro, Mass...	C. I. & C. L.	4 to 16	1,660		28.60	$	0.14		2	223			50 to 62
2	Bay City, Mich....	C. I. & Wyckoff.	3 to 20	9,475	3,325	44.	16.01	1.	.06	17	387	23	670	35 to 38
3	Brockton, Mass...	W. I., C. L. & C. I.	6 to 30	24,108	1,210	54.5	4.58	.89		39	488	79	540	47 to 56
4	Burlington, Vt ...	C. L., W. I. & C. I.	4 to 24	7,433	3,515	35.65	30.	1.4	2.8	8	195	38	486	70 to 85
5	Concord, N. H ..			8,798		56.3				4	243	19	682	
6	Fall River, Mass..	C. I.	6 to 24			76.1				37	780	28	776	80
7	Fitchburg, Mass ..	W. I., C. L. & C. I.	2 to 30	10,938		59.34	6.78	.28	1.54	19	408	13	442	155 to 160 75 to 80
8	Lynn, Mass.......	W. I., C. L. & C. I.	2 to 20	6,304		124.		1.3		3	786	11	931	50 to 65
9	Middleboro, Mass.	C. I.	4 to 12	2,075		14.				3	102	10	140	45 to 60
10	New Bedford, Mass	W. I. C. L. & C. I.	4 to 30	31,080	22,453	76.3	13.88		1.1	17	624	29	864	29 to 38
11	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	7,858		43.1	10.60	.7	2.9	5	198	8	227	45 to 50
12	Newton, Mass ...	C. I.	4 to 20	34,576		120.	15.23	.09	2.8	45	805	41	643	84
13	Oberlin, Ohio.....	C. I.	4 to 12	1,121		7.8	1.40	.25	.3	2	72	1	45	27 to 32
14	Plymouth, Mass..	W. I. & C. L.	2 to 20	4,879½		34.	5.30	.1	10.5	1	106	5	312	
15	Reading, Mass....	C. I.	4 to 12	1,976		20.4	none	none	none	3	111	3	193	68 to 78
16	Springfield, Mass.	W. I., C. L. & C. I.	¾ to 36	39,194	5,182	123.6	6.03	.41	7.9	76	793	133	1,440	100 to 120 30 to 35
17	Taunton, Mass ...	C. I.	4 to 20	1,393		70.7	25.33		1.2	24	705	14	480	45 to 50
18	Waltham, Mass...	C. I. & C. L.	2 to 24	3,010		47.8	8 10	.5		10	281	17	602	56
19	Woonsocket, R. I.	C. I.	4 to 20	3,690		37.	2.92	.43	0	5	462	10	397	90 to 115
20	Yonkers, N. Y. . .	C. I.	4 to 30	36,406		56.7	26.00	1.5	0	59	582	35	364	

1895.—V.—DISTRIBUTION—SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind of Pipe.	17 Service Pipe. Size of Pipe in Inches.	18 Service Pipe. Length Extended Feet.	19 Service Pipe. Length Discontinued Feet.	20 Service Pipe. Length in Use. Miles.	21 Service Taps. No. Added.	22 Service Taps. Total in Use.	23 Av. Length of Service.	24 Av. Cost of Service.	25 Meters. Number added.	26a Meters. Now in Use. Domestic.	26b Meters. Now in Use. Manu-fac'ing.	27 Motors and Elevators. No. added.	28 Motors and Elevators. Total in Use.
1	Attleboro, Mass...									$	20	619			1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	3/8 to 8				14	1,851			43	559			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	3/4 to 6	16,640	263.	20.7	371	4,245	43.3	8.32	485	2,963			
4	Burlington, Vt ..	Gal. I. and Lead.	1/2 to 6	3,739	56.	16.	134	2,969	27.9	9.00	179	1,186	75	3	29
5	Concord, N. H....			2,185		13.5		3,055							
6	Fall River, Mass...	Lead.	1/2 to 2				308	6,372			325	5,212			
7	Fitchburg, Mass...	W. I., C. L. & C. I.	3/4 to 8	6,338		42.8	140	3,876	58.0	14.06	231	1,652	126	11	66
8	Lynn, Mass.......	W. I., C. L., Gal., Ada.	3/4 to 10	14,204	3,850.	89.	279	11,023			316	1,206			
9	Middleboro, Mass.	L., W. I. lined with C.	3/4 to 2	1,431		7.8	27	697	55.0		17	240	16	0	5
10	New Bedford, Mass	Lead and Cast Iron.	1/2 to 8	11,043	324.	50.16	260	8,027	42.0	10.52	33	196	58	11	79
11	New London, Ct. .	W. I., C. L., G., L., C. I.	1/2 to 4	2,408		9.7	108	2,663	22.3	10.85	9	167			22
12	Newton, Mass. ..	Lead, W. I. and C. I.	1/2 to 6	22,490	4,250.	67.8	332	5,917	62.0	12.90	400	4,557	23		16
13	Oberlin, Ohio......	Gal. and Lead.	3/4 to 1				44	443	25.0	8.00	35	127	10	0	0
14	Plymouth, Mass...	Lead and Cem't Lined.	1/2 to 1	192		5½	43	1,620	17⅔	3.04					1
15	Reading, Mass ..	G. I., C. L., L. L. & C. I.	3/4 to 6	4,943	none	9.3	69	753	71.0	30.83	45	87		2	4
16	Springfield, Mass..	W. I. and C. I.	1/2 to 6				418	7,900			260	2,207		18	162
17	Taunton, Mass...	Cem't L. and W. I.	3/4 to 3		5,352.76	37.1	95	3,843		18.68	56	1,228	138	1	14
18	Waltham, Mass....	C. I. & W. C. L.	3/4 to 6	3,485	75.	33.8	43	3,035	72.4	36.85	0	72		0	6
19	Woonsocket, R. I.	Lead and Iron.	5/8 to 6	1,749			93	1,760	18.6	11.43	84	1,469	42		6
20	Yonkers, N. Y....	Lead and C. I.	3/8 to 8				210	3,650			224	3,590	116	1	9

STATISTICS FOR 1896.

1896—I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Con'uction.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. Coal Used.	Per Ct. Ashes.	Price per Ton of 2240 Lbs.
1	Attleboro, Mass.....	1873	Circular Well near River.	Pump to S. P.	Blake & Deane.	Bituminous.		$4.60
2	Bay City, Mich......	1872	Lake Huron.	Pump Direct	Holly.	Coal Slack.	8.76	4.77
3	Brockton, Mass......	1880	Storage Reservoir	Pump to S. P.	Worthing'n & Holly.	Bituminous.		
4	Burlington, Vt.......	1867-8	Lake Champlain.	Pumping.	Worthington.	Anthracite.		4.65-5.10-5.35
5	Fitchburg, Mass.....		Storage Reservoirs.	Gravitation.				
6	Lynn, Mass.........	187 0	Storage Reservoirs.	Pump to R.	Leavitt & Loretz.	Bituminous.		4.14
7	Middleboro, Mass...	1885	Large Well.	Pump to S. P.	Deane.	Bituminous.		4.50
8	New Bedford, Mass..	1866-9	Storage Reservoir.	Gravity and Pump.	McAlpine & Worthington	Bituminous.	8½	4.00
9	New London, Conn..	1872	Storage Reservoir.	Grav. & Pump by Water Motor	(Lang & Goodhue)			
10	Newton, Mass.......	1876	Filter Basin Springs & Wells.	Pump to R.	Blake & Worthington.	Bituminous.	6.00	4.18
11	Oberlin, Ohio.......	1887	Vermillion River.	Pump to S. P.	Deane.	Bituminous.		2.25
12	Plymouth, Mass.....	1855	Great and Little South and Lout Ponds.	Gravity and P.	Worthington.	Bituminous.		4.75
13	Reading, Mass......	1890	Filter Gallery.	Pump to S. P.	Blake.	Bituminous.		4.80 4.90
14	Springfield, Mass..	1864- 1873-75	Reservoirs.	Gravitation.				
15	Taunton, Mass......	1876	Elders Pond.	Gravity and Pump.	Holly & Allis.	Bituminous.		3.85
16	Waltham, Mass......	1872	Charles River.	Pump to R.	Worthington.	Bituminous.	11.00	4.28
17	Woonsocket, R. I...	1884	Crooks Falls Brook	Pump to Tanks.	Worthington.	Bituminous.	7.00	4.38
18	Yonkers, N. Y......	1874	Storage Reservoir.	Pump to R. & Tank	Wright & Worthington.	Ant'racite & Bit.	10.5	4.13

1896—I. GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, Lbs.	4. Lbs. of Wood. 3.	5. Total Fuel Consumed for the Ye'r Lbs.	6. T'l Pump'ge for the Year in Gallons.	7. Av'ge Static Head ag'st Pumps.	8. Av. Dy'mic Head ag'st Pumps, ft.	9. No. Gallons Pumped Per Lb. of Coal.	10. Duty in Ft. Lbs. Per 100 lbs. of Coal, No Deductions.	11. Cost per Mil'on Gal. Pumped into Res'voir Fig. on Pmp. Station Ex's.	12. Cost per Mil. Gals. Rai'd 1 ft. High. Fig. P. Sta. Ex	13. C'st pr Mil. Gals. P'm'd into Res'vr Fig on To'l Main'ance	14. C'st pr Mil Gal. r'sd 1 ft high Fig on Total main'ance
1	455,881	1,000	456,881	115,559,540	160	B175 D188	253	39,750,000	$18.70	$ .0996	$ 143.50	$ .765
2	3,535,760			1,909,523,471		113			7.29	.064	44.42	0.393
3	491,275			397,982,808		43	810.10		5.08	.118	96.00	2.23
4				305,817,025	289	316			34.59	0.109	172.19	0.535
5												
6	1,146,050 1,598,500	300 600	1,146,350 1,599,100	623,382,276 1,037,462,650		162.3 165.25	543.9 648.7	73,607,452 89,426,269	6.55	.0399	79.06	.4816
7	473,270		473,270	77,252,570	180	201	165.55	28,199,725	32.11	.16	89.61	.445
8	2,884,200	473	2,884,673	1,975,205,472	125.7 141.5 124.9	135.6 151.52 129.51	642 785 435	72,355,552 54,999,360 84,774,912	5.72	4.29	38.72	29.04
9												
10	1,584,800	8,000	1,592,800	666,259,000	234	254	418	111,000,000	12.62	.05	160.84	.63
11	290,000		290,000	24,584,700	80	80	84.8	5,656,000	49.00	.61	190.80	2.38
12	228,100		228,100	105,399,360	66		462.07	25,434,181	15.41	0.2323	90.42	1.37
13	524,703		524,703	72,734,860	219	240	139	3,177,050	43 59	.181	186.78	.778
14												
15	1,011,900		1,011,900	427,437,849		69.83	602.36	34,096,561	10.94	.1567	166.55	2.39
16	2,065,000			555,213,476	165	186	270	42,810,750	12.00	.063	69.15 101.36	.0304
17	953,000	258	953,774	259,015,107	238	239	271	54,198,946	14.90	.062	117.28	.48
18	4,309,543			1,243,182,067	185		288.4		11.00			

1896.—II.—FINANCIAL.

Number.	Name of City or Town.	Receip's from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
		$	$	$	$	$
1	Attleboro, Mass			15,292.29		
2	Bay City, Mich	17,322.88	5,741.98	23,064.86	159.10	22,223.96
3	Brockton, Mass	40,333.16	9,174.69	49,507.85	183.04	49,690.89
4	Burlington, Vt	36,513.32	4,621.78	41,135.10	1,896.08	43,031.18
5	Fitchburg, Mass	51,204.66	13,968.33	65,172.39		
6	Lynn, Mass	128,047.11	48,768.51	176,815.62	9,357.83	186.173.45
7	Middleboro, Mass	7,751.65	2,741.65	10,439:30	76.79	10,570.09
8	New Bedford, Mass	85,866.74	8,290.33	94,157.07	103.00	94,260.07
9	New London, Conn			41,104.39		41,104.39
10	Newton, Mass	78,958.71	5,300.00	96,641.98		
11	Oberlin, Ohio	3,584.21	380.00	3,964.21	644.96	4,609.17
12	Plymouth, Mass	15,455.17	1,397.25	16,852.42	235.29	17,087.71
13	Reading, Mass	7,346.24	137.75	7,483.99	70.31	7,554.30
14	Springfield, Mass	129,175.52	55,222.65	184,398.17	24,148 39	208,546.56
15	Taunton, Mass	38,541.69	10,836.86	49,378.55	310.12	49,688.67
16	Waltham, Mass	52,395.11	6,504.16		1,605.28	60,504.55
17	Woonsocket, R. I.	29.373.13	7,834.38	37,207.51	101.21	37,308.72
18	Yonkers, N. Y.	83,019.73	26,757.39		5,009.91	

1896.—II.—FINANCIAL.—Continued.

Number.	Receipts from Public Funds.					K	AA	BB		
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.	Miscellaneous Expenses.	Total Maintenance.
1	$ 6,488.00	$ 375.00	$	$ 287.00		$ 22,484.23	$ 4,552.10	$ 10,984.03	$ 982.58	$ 16,518.71
2					$ 26,110.00	49,333.96	18,731.58	26,110.00		44,841.58
3	3,000.00					52,690.89	8,736.39	29,725.00		38,461.39
4	3,360.00		1,889.91	6,069.91	3,557.07	52,658.16	42,008,16	10,650.00		52,658.16
5							14,740.00			40,530.33
6							58,005.82	73,346.24		131,352.06
7					2,000.00	12,570.09	4,222.44	2,700.00		4,222.44
8					46,883.33	141,143.40	29,588.85	46,883.33		76,472.18
9					24,540.00	41,104.39	5,712.52	24,540.00		30,252.52
10	15,200 00	130.00	2,700.00	950.00	120.00	116,605.98	17,271.52	89,900.00		17,271.52
11					2,700,00	7,309.17	2,092 70	2,600.00		4,692.70
12						17,087.71	5,466.07	4,065.60		9,531.67
13	3,330.00				4,570.00	15,454.30	5,617.21	7,968.53		13.585,74
14	16,820.00	1,491.80	4,975.58	4,073.95	25.000.00	261,822.89	21,022.95	96,000.00		124,660.15
15	3.500.00	1,794.79	800,00	532.06		76,897.15	21,292.01	49,893.00		71,185.01
16						60,504.55	21,872.80	16,520.00		38,392.80
17	41,642.50	1,467.26	2,096.26	851.16	11,000,00	67,365.90	11,124.39	19,254.71		30,379,10
18	18,210.00				2,035.53	135,032.56	37,067.02	73,950.00	21,828.03	

1896.—III.—CONSUMPTION.

Number.	Name of City or Town.	1	2	3	5	6	Percentage of Total Consumption Metered.	7	8	9	10
		Estimated Population.							Gallons per Day.		
		Total at Date.	On Line of Pipe.	Supplied at date.	Quantity used through Domestic Meters—Gals.	Quantity used through Man'f'tring Meters—Gals.		Average Daily Consumption, Gallons.	Each Inhabitant.	Each Consumer.	Each Tap.
1	Attleboro, Mass.....	8,500	7,000	6,500	115,559,540			315,612	37.1		48.5
2	Bay City, Mich.....	33,000	20,000	14,000	53,762,412	52,977,831	10.57	2,758,261	83.0	197.0	1,484.0
3	Brockton, Mass.....	35,000	32,000	31,000	116,536,470	40,604,662		1,087,111	31.06	34.90	239.80
4	Burlington, Vt......	17,300	16,900	16,700	107,786,961	18,291,510		835,565	48.0	50.0	272.0
5	Fitchburg, Mass....	26,500	23,000	20,300	56,900,000	279,000,000			94.0	123.0	670.0
6	Lynn, Mass.........	69,361		67,139	249,906,830			4,551,789		67.8	
7	Middleboro, Mass...	Fire D. 4,200 7,000	4,000	3,700					50.25	57.0	292.0
8	New Bedford Mass..	59,000	49,530	45,570	40,475,088	316,760,610		5,259,017	89.0	108.0	623.0
9	New London, Conn.	15,500	15,000	14,500				1,385,134	89.0	95.5	505.0
10	Newton, Mass.......	29,500	29,100	28,900	275,000,000	55,000,000		1,812,484	614.10	627.10	289.0
11	Oberlin, Ohio.......	4,600	3,500	2,000	6,000,000	1,900,000	33.0	67,200	14.6	33.6	143.0
12	Plymouth, Mass....										
13	Reading, Mass......	4,750	4,160	3,600	5,545,170	1,031,483		199,273	41.95	47.89	245.41
14	Springfield, Mass...	54,812	48,800	42,500	372,253,326		21.0	4,819,828	88.0	113.0	581.0
15	Taunton, Mass......	27,093	26,700	26,361	51,276,720	92,735,534		1,167,863	43.0	44.0	296.0
16	Waltham, Mass......	21,500	21,000	20,500	33,441,260			1,521,133	70.0	72.0	490.0
17	Woonsocket, R. I...	28,500	26,500	26,500				708,227	24.9	26.7	359.0
18	Yonkers, N. Y.......	40,000	34,000	33,000	248,223,254	365,141,844	50.3	3,331,802	83.0	100.0	910.0

1896.—IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Distribution Pipe in Inches.	3 Length Extended During Year, Feet.	4 Length Discontinued During Year, Feet.	5 Total Length in Use, Miles.	6 Cost of Repairs Per Mile.	7 Number of Leaks Per Mile.	8 Length of Pipe Less than 4" Diameter, Miles.	9 Hydrants. No. Added.	10 Hydrants. Total in Use.	11 Stop Cocks. No. Added.	12 Stop Cocks. Total in Use.	15 Range of Pressure Pounds.
1	Attleboro, Mass...	C. I. & C. L.	4 to 16	5,210		29.58	$	0.13		11	234			50 to 62
2	Bay City, Mich....	C. I. & Wyckoff.	3 to 20	2,554	6,830	43.25	13.63	1.	.06	6	393		662	35 to 38
3	Brockton, Mass...	W. I., C. L. & C. I.	6 to 30	14,714.3	25	56.84	3.26	.56		31	519	36	576	47 to 56
4	Burlington, Vt....	C. L., C. I. & W. I.	4 to 24	9,992	8,051	36.	9.	.75	14.619	7	202	27	513	70 to 85
5	Fitchburg, Mass ..	W. I., C. L. & C. I.	2 to 30	14,168		62.09	5.32		1.54	17	425	16	458	{ 155 to 160 75 to 80
6	Lynn, Mass.......	W. I., C. L. & C. I.	2 to 20	2,659		108.8		146.		3	170	5	936	50 to 65
7	Middleboro, Mass.	C. I.	4 to 12	8,010.8		$15\frac{3}{8}$				6	108	8	148	45 to 60
8	New Bedford, Mass	W. I. C. L. & C. I.	4 to 36	51,259	8,358	84.4116	9.80	14.	6,420 ft	46	670	65	928	26 to 44
9	N. London, Conn.	W. I., C. L. & C. I.	4 to 20	8,623		44.7	18.46	1.	2.04	9	207	19	246	45 to 50
10	Newton, Mass...	C. I.	4 to 20	29,874		$125\frac{7}{10}$	16.06	13.	2.9	35	840	41	684	84
11	Oberlin, Ohio.....	C. I.	4 to 12	1,730		8.1			.33	2	74	3	48	27 to 32
12	Plymouth, Mass..	W. I. & C. L.	2 to 20	668		34.	9.38	1.	10.5	3	116	7	319	
13	Reading, Mass...	C. I.	4 to 12	666		20.0412					111	2	195	68 to 78
14	Springfield, Mass.	W. I., C. L. & C. I.	$\frac{3}{4}$ to 36	30,351	8,415	127.8	11.69	.42	39,779 ft	48	841	105	1,545	{ 100 to 120 30 to 35
15	Taunton, Mass...	C. I.	4 to 20	4,349		71.56	29.85	4.	6,415 ft	19	724	9	492	45 to 50
16	Waltham, Mass...	C. I., W. I. & C. L.	2 to 24	1,951		48.1	6.57	1.		10	291	21	623	58
17	Woonsocket, R. I.	C. I.	4 to 20	9,028		42.6	1.76	.23		23	514	19	416	90 to 115
18	Yonkers, N. Y... .	C. I.	3 to 30	11,163		60.8	19.00	1.5	.84	18	628	9	373	

1896.—V.—DISTRIBUTION—SERVICE PIPES.

		16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
												Now in Use.			
Number.	Name of City or Town.	Kind of Pipe.	Size of Pipe in Inches.	Length Extended Feet.	Length Discontinued Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number added.	Domestic.	Manu-fac'ing.	No. added.	Total in Use.
1	Attleboro, Mass...									$	54		673		1
2	Bay City, Mich....	Lead, W. I. & Wyckoff.	$\frac{3}{8}$ to 8				7	1,858			61	620			
3	Brockton, Mass....	W. I., L. L., C. L & C. I.	$\frac{3}{4}$ to 6	18,586	433.	24.17	336	4,581		9.06	419	3,382			
4	Burlington, Vt ..	Gal., Lead.	$\frac{1}{2}$ to 6	3,241	211.	16.5	98	3,067	32.34	9.17	291	1,501	51	1	30
5	Fitchburg, Mass...	W. I., C. L. & C. I.	$\frac{3}{4}$ to 8	6,197		44.06	175	4,051	35.	11,20	93	1,695	176	4	70
6	Lynn, Mass.......	I., C. L., Ada. Gal., L. L.	$\frac{3}{4}$ to 10	11,116	925.	90.9	264	11,267			355	1,561			
7	Middleboro, Mass.	L., W. I. and C. L.	$\frac{3}{4}$ to 3	1,201		42469f	25	722	50.		17	254	19		5
8	New Bedford, Mass	Lead and Cast Iron.	$\frac{1}{2}$ to 10	15,718	412.	53.06	420	8,447	36.	15.01	112	307	59	2	81
9	New London, Ct. .	G. I., Gal., C. L. and L.	$\frac{1}{2}$ to 4	1,725		10.	78	2,741	19.	13.74	20	187		1	23
10	Newton, Mass. ..	Lead, W. I. and C. I.	$\frac{1}{2}$ to 6	23,097	5,828.	71.	359	6,276	61.	25.50	443	4,958	25	1	17
11	Oberlin, Ohio......	Gal., Lead.	$\frac{3}{4}$ to 2				28	471	25.	8.00	37	169	5	0	0
12	Plymouth, Mass...	Lead and Cem't Lined.	$\frac{1}{2}$ to 1	423		5 5	43	1,664	$17\frac{2}{3}$	4.50					1
13	Reading, Mass ..	G. I., C. L., L. L. & C. I	$\frac{3}{4}$ to 6	4,881		10.27	59	812	82.7	26.58	48	135		0	3
14	Springfield, Mass..	W. I. and C. I.	$\frac{1}{5}$ to 6				398	8,298			92	2,299			172
15	Taunton, Mass....	Cem't L. and W. I.	$\frac{3}{4}$ to 3	1.18m	5,723.42	38.33	119	3,955		19.47	76	1,443	1,297	0	14
16	Waltham, Mass....	C. I. W. I. & C. L.	$\frac{3}{4}$ to 8	4,139	464.	34.1	43	3,085	70.5	24.85	3	75		0	6
17	Woonsocket, R. I.	Lead and Iron.	$\frac{5}{8}$ to 6	1,787		5.5	112	1,872	17.2	12.78	88	1,552	47	3	9
18	Yonkers, N. Y.....	Lead and C. I.	$\frac{3}{8}$ to 8				266	3,790			256	3,836	126		9

PROCEEDINGS.

MONTHLY MEETING.

Young's Hotel,
Boston, February 9, 1898.

President Kent in the chair. Members and guests were present as follows:

ACTIVE MEMBERS.

Everett L. Abbott, Solon M. Allis, Francis E. Appleton, Charles H. Baldwin, Lewis M. Bancroft, R. S. Bartlett, George E. Batchelder, Joseph E. Beals, James F. Bigelow, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, Charles E. Chandler, William F. Codd, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, F. H. Crandall, A. A. Forbes, F. F. Forbes, E. N. French, Frank L. Fuller, J. C. Gilbert, Albert S. Glover, J. A. Gould, E. H. Gowing, Francis C. Green, E. A. W. Hammatt, George W. Harrington, John C. Haskell, F. S. Hollis, Horace G. Holden, Willard Kent, Patrick Kieran, Frank E. Merrill, Leonard Metcalf, Charles F. Murphy, Frank L. Northrop, W. H. Richards, W. W. Robertson, A. H. Salisbury, George A. Stacy, Edwin A. Taylor, Lucian A. Taylor, W. H. Thomas, D. N. Tower, Charles K. Walker, Wm. W. Wade, John C. Whitney, G. E. Winslow, E. T. Wiswall.

ASSOCIATE MEMBERS.

Chadwick Lead Works, by A. H. Brodrick.
Deane Steam Pump Co., by Messrs. Hayes and Bellows.
Ludlow Manufacturing Co., by H. F. Gould.
Hersey Manufacturing Co., by J. Edward Spofford.
Henry F. Jenks, Pawtucket, R. I.
Lead Lined Pipe Co.,
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bowd.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, Providence, R. I., by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Union Water Meter Co., by F. L. Northrop.
R. D. Wood & Co., by Jesse Garrett.
H. R. Worthington, by J. M. Betton.

GUESTS.

Norris J. Alton, Calvin Claflin, J. J. Moore, W. E. Maybury, J. W. McGeary, L. B. Palmer and H. L. Thomas.

The following named gentlemen were elected resident active members:

Benjamin R. Chapman, Civil Engineer, Brockton, Mass.; J. F. Gleason, Foreman of Construction, Quincy, Mass.

The first paper of the afternoon was read by F. H. Crandall, Superintendent, Burlington, Vermont, his subject being "Loss of Water from Pipes." Mr. Brackett, Mr. Whitney, Mr. Richards, Mr. Kieran, Mr. Stacy, Mr. Holden and Mr. Fuller took part in the discussion which followed.

Mr. H. G. Holden, Superintendent, Nashua, N. H., gave a description of the laying of a 24-inch main under the Nashua river. Experiences in similar work were told by Messrs. Crandall, Gowing, Brackett and Gilbert.

Mr. Solon M. Allis, of Malden, Mass., read a paper entitled, "Experiences in the Arid Southwest."

The meeting then adjourned.

QUARTERLY MEETING.

Young's Hotel,

Boston, March 9, 1898.

The following members and guests were present:

ACTIVE MEMBERS.

Francis E. Appleton, George E. Batchelder, Joseph E. Beals, George Bowers, Dexter Brackett, John T. Cavanagh, George F. Chace, E. J. Chadbourne, G. L. Chapin, John C. Chase, Harry W. Clark, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, George K. Crandall, Lucus Cushing, O. A. Doane, John W. Ellis, B. R. Felton, Charles R. Felton, E. N. French, Alphonse Fteley, Frank L. Fuller, J. C. Gilbert, J. F. Gleason, T. C. Gleason, Albert S. Glover, Frederick W. Gow, James H. Harlow, John C. Haskell, T. G. Hazard, Jr., F. S. Hollis, H. N. Hyde, Willard Kent, Frank C. Kimball, James W. Locke, Frank E. Merrill, Leonard Metcalf, Edward C. Nichols, Frank L. Northrop, Edward Phillips, J. B. Putnam, Walter H. Richards, W. W. Robertson, William T. Sedgwick, John E. Smith, George A. Stacy, J. D. Hardy, J. A. St. Louis, Charles H. Swan, Wm. H. Thomas, W. H. Vaughan, Charles K. Walker, William W. Wade, J. Alfred Welch, John C. Whitney, George E. Winslow, E. T. Wiswall, M. N. Baker.

ASSOCIATE MEMBERS.

Coffin Valve Co., by Mr. Weston.
Deane Steam Pump Co., by F. H. Hayes and L. E. Bellows, General Manager.
Drummond, M. J., New York City, N. Y., by W. G. Briggs.
George E. Gilchrist, by H. M. Libbey.
Mellin S. Harlow, Boston, Mass.
Kennedy Valve Co.
Hersey Manufacturing Co., by Albert S. Glover.
The Hydraulic Construction Co., by M. R. Ryder.
Jenks, Henry F., Pawtucket, R. I.
The McNeal Pipe and Foundry Co., by I. S. Haines, Treasurer.
Lead Lined Pipe Co., by T. E. Dwyer.
National Meter Co., by J. Edward Spofford.
Neptune Meter Co., by H. H. Kinsey.
Perrin, Seamans & Co., by H. L. Bond.
Rensselaer Manufacturing Co., by F. S. Bates.
Builders' Iron Foundry, by T. C. Clifford.
Anthony P. Smith, by W. H. Van Winkle.
Sumner & Goodwin Co., by F. D. Sumner.
Union Water Meter Co., by J. P. K. Otis.
R. D. Wood & Co., by Mr. Newhall.
H. R. Worthington, by J. M. Betton.

GUESTS.

C. M. Ames, C. F. Chase, F. B. Endicott, C. E. Fowler and G. L. Turner.

The following named gentlemen were elected active resident members:

George E. Manning, C. E., New London, Conn.
William Walter Ewell, Supt. Water Works, Quincy.
J. D. Hardy, Supt. Holyoke Water Works.
James L. Tighe, Engineer, Holyoke Water Works.
Charles D. Colson, Water Commissioner, Holyoke.
Thomas F. Greaney, Water Commissioner, Holyoke.
John J. Sullivan, Water Commissioner, Holyoke.

Charles E. Fowler, Superintendent and Engineer of the Poughkeepsie Water Works, read a paper entitled "Operation of a Slow Sand Filter." The subject was discussed by Mr. Hazen, Mr. Clark, Mr. Haskell and Prof. Sedgwick.

On motion of the Secretary the thanks of the Association were extended to Mr. Fowler for his paper.

Adjourned.

OBITUARY.

WILLIAM M. HAWES.—Died February 16th, 1898, aged 65 years. Joined this Association June 16th, 1886.

Mr. Hawes was for many years a member of the Board of Water Commissioners of the city of Fall River, Mass., and as such took an active interest in the welfare of this Association. He was a constant attendant at its meetings until stricken with the disease which finally resulted in his death. His genial good fellowship and kindly disposition won the friendship of all the members of the Association by whom his death is sincerely mourned.

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DATE DUE

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